UNION MINING COMPANY
BALTIMORE, MD.

PROPRIETORS

MOUNT SAVAGE FIRE BRICK WORKS

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MD.

UNION MINING COMPANY

CATALOGUE H

PERTAINING TO

FIRE BRICK

MANUFACTURED BY

THE UNION MINING COMPANY

(Incorporated 1841)

PROPRIETORS OF THE

MOUNT SAVAGE FIRE BRICK WORKS

Manufacturing Plants:
MOUNT SAVAGE, MD.

General Offices:
FIDELITY BUILDING
BALTIMORE, MD.

PREFACE

IT is our aim, in presenting this catalogue to our friends that it should not only describe our products, but should be a source of general information and help. The data has been taken from sources of recognized authority.

We extend our thanks to the Mellon Institute of Industrial Research, Pittsburgh, and to Mr. Raymond M. Howe, Senior Fellow of the Refractories Manufacturers Association's Fellowship, for assistance and data; and to American Society for Testing Materials; The Metallurgists and Chemists' Handbook, compiled by Donald M. Liddell, Captain, Sig. R. C., A. S.; Chas. E. Ferris, B. S., Professor of Mechanical Engineering, University of Tennessee; Mr. Albert Sauveur, of Sauveur & Boylston, Metallurgical Engineers, Cambridge, Mass., for permission granted us to copy from their publications.

IT IS NATURAL for one to go to the source of production of their raw material when attempting to describe the merits of their manufactured product.

Our clays, both flint and plastic, come from the celebrated Savage Mountain (Maryland) of the Allegheny Range.

About the year 1839 experimental work was done with these clays; these experiments showed they were extremely refractory and fire brick made from them gave unusually satisfactory service.

Two years later the manufacture of brick was begun on a commercial scale, and "Mount Savage" fire brick have been made continuously at Mount Savage, Maryland, since that time.

Constancy of volume under extremely high temperature is a recognized merit of "Mount Savage" flint clay.

Reference to chart A—reproduced from Technologic Paper No. 7, by A. V. Bleininger, Ceramic Chemist, and G. H. Brown, Assistant Ceramic Chemist, of the Bureau of Standards, Department of Commerce, U. S. A., shows how satisfactorily our clay ranked in this test, none of the seven other

POROSITY-TEMPERATURE RELATIONS OF EIGHT FIRE CLAYS AS DETERMINED BY THE BUREAU OF STANDARDS.

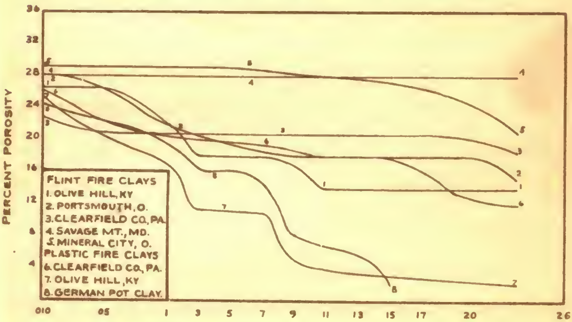


CHART A—TEMPERATURE IN CONES

clays approaching it for constancy of volume.

It is impossible to manufacture brick from flint clay alone, it being necessary to add plastic clay as a binder. It is a recognized fact that plastic clays are not quite so refractory as high quality flint clays, consequently the refractoriness of a brick is reduced or in-

creased by the proportions of flint and plastic clays used. Chart B, prepared by Raymond M. Howe, Senior Fellow of the Refractories Manufacturers Association's Fellowship at the Mellon Institute of Industrial Research, shows by the heavy line the ideal relation between Composition and Refractoriness, as well as

RELATION BETWEEN COMPOSITION AND REFRACTORINESS.

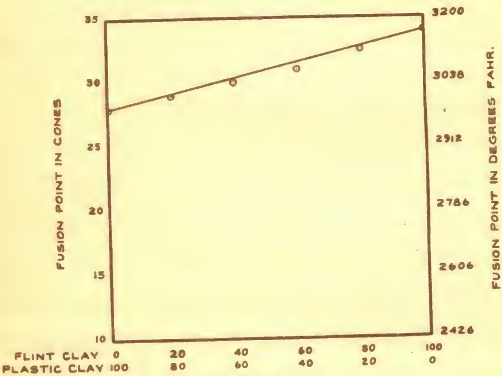


CHART B

how nearly brick made from varying proportions of our flint and plastic clays, as represented by the small circles, approach this ideal.

It has long since been determined that no one process of manufacture will produce a brick that will be best adapted for all pur-

poses. This question has been closely studied by us in an endeavor to furnish such brick as will, in our opinion, give the best results in the many classes of furnaces in which our brick are used. Customers can help us and themselves by giving full information as to their furnaces, methods of operating, fuel used, etc.

Our works are divided into two parts, each being operated as a separate unit, equipped with its own building and electric power drive, clay storage bins, wet and dry pans, pug mill, represses, dry floors and kilns. By this arrangement an accident might cause one portion to be idle while the process of manufacture would not be interrupted in the other. Our kiln capacity is sufficient to take care of an output considerably larger than we maintain.

Being owners of very extensive coal mines, adjacent to the plant, we have a great advantage over many of our competitors who are dependent upon outside sources for their fuel supply. Especially is this the case during strikes, car shortages or when there is a scarcity of coal in the open market.

Our plant is located at Mount Savage, Allegany County, Maryland. Our car supply is obtained from the Baltimore and Ohio, Pennsylvania and Western Maryland Railroads, all of which quote freight rates to all points. We are much better off in this respect than the manufacturing concern that is dependent upon a single Railroad for its cars and freight rates.

MOUNT SAVAGE

"MOUNT SAVAGE" fire brick are strongly recommended for use in work where high heats are obtained and maintained, where there are sudden changes in temperature, particularly from extremely high to low temperature, and where slag action is encountered.

Mount Savage clays will withstand these conditions with the minimum amount of shrinkage, expansion or spalling. These very desirable qualities make them especially adapted for use in malleable, heating and puddling furnaces, open hearth checkers, blast furnaces, oil fired furnaces, power plants (particularly those equipped with automatic stokers and forced draft) and wherever fire clay brick of highest grade is required. To meet the varied conditions encountered, the process of manufacture, texture and burn of the brick

is varied. The brick are branded "Mount Savage"—"Mount Savage Malleable"—"Mount Savage Stoker", etc.

They rank among the leading High Heat Duty Brick, under the Standard Definitions for Clay Refractories, as adopted by the American Society for Testing Materials. These Definitions are given in full on pages 93, 94 and 95 of this catalogue.

"UMINCO"

THERE are many places where first class brick are required, but where it is not necessary to use as refractory a brick as our "Mount Savage". To meet this demand, after a great deal of experimental work in connection with the Refractories Manufacturers Association's Fellowship at the Mellon Institute of Industrial Research, we placed on the market a new fire brick, branded "Uminco". It comes well within the limits of a High Heat Duty Brick.

"Uminco" brick are made from the same clays as "Mount Savage" but of varying proportions.

"REFRACTO"

Our "Refracto" brick have been on the market for many years. They are made from the same clays as our "Mount Savage," and rank as an Intermediate Heat Duty Brick.

They are dense, well burned and are unexcelled for boiler settings, the friction zone of lime kilns, cupolas, brick kilns, flues, and other work where a second or third quality brick will not give satisfactory service.

"CARBURETER"

Our "Carbureter" is the brick we offer to the Gas Industry for use in the machines in which water gas is manufactured.

Close study was made by us of the conditions encountered in this industry and what was required of fire brick. A combination of our superior clays and process of manufacture has enabled us to offer in "Carbureter" a brick that will stand the sudden changes of temperature encountered in this industry with the minimum amount of spalling; a brick that absorbs very little oil; a brick that resists carbonization.

These and many more good features of "Carbureter" fire brick are covered more fully in a special booklet we issue on this subject which will be furnished upon request.

FIRE CLAY

TO obtain the most satisfactory results from even the best grades of fire brick the question of the material used in setting or laying the brick is a vital one. It is a great mistake to think low grade clays will give satisfactory results. It is a common occurrence where these are used for them to fuse at low temperatures, causing brick to fall from an arch or become loose in a wall. This gives the heat an opportunity to penetrate between the courses of brick, thus attacking from all sides instead of one surface only.

We ship large quantities of our Mount Savage clay to be used in setting brick. For general purposes we furnish our plastic clay, ground very fine and screened. Where the temperatures encountered are severe a more refractory article is required, in which cases we furnish a mixture of our flint, plastic and calcined clays, very finely ground. We ship in bulk, or in sacks, in any quantity desired. Where less than car lots of clay are ordered it must be shipped in sacks, unless it goes with a car of brick.

IMPORTANT

Never add any foreign material to ground fire clay in making fire brick mortar. This is sometimes done to make the mortar set firmly without the application of heat, to offset the natural shrinkage of the clay, or to cause it to burn to a dense structure by reason of decreased refractoriness.

Extensive experiments were conducted by the Refractories Manufacturers Association's Fellows at the Mellon Institute of Industrial Research with plastic clays to which had been added Portland Cement, Lime, Asbestos, Water Glass Solution, Salt and Carborundum. In each case it was demonstrated that the refractoriness of the clay was reduced, the extent of the reduction depending on the amount of the foreign material added; for instance:—

				Fusion Point °C	Fusion Point °F
100%	Fire Clay			1730	3146
96%	Fire Clay	4%	Cement	1670	3038
90%	" "	10%	"	1430	2606
80%	" "	20%	"	1390	2534
60%	" "	40%	"	1290	2354
96%	" "	4%	Lime	1590	2894
92%	" "	8%	"	1480	2696
88%	" "	12%	"	1350	2462
84%	" "	16%	"	1330	2426
97%	" "	3%	Asbestos	1700	3092
94%	" "	6%	"	1520	2768
91%	" "	9%	"	1500	2732
96%	" "	4%	Water Glass	1720	3128
92%	" "	8%	" "	1710	3110
88%	" "	12%	" "	1700	3092
84%	" "	16%	" "	1660	3020
80%	" "	20%	" "	1650	3002
95%	" "	5%	Salt	1650	3002
90%	" "	10%	"	1410	2570
85%	" "	15%	"	1230	2246
95%	" "	5%	Carborundum	1710	3110

Later, experiments were conducted to show how the addition of calcined clay to the same plastic clay would increase the refractoriness of the latter with the following results:—

					Fusion Point °C	Fusion Point °F
100% Plastic Clay					1730	3146
75% Plastic Clay		25% Calcined Clay			1740	3146
50%	" "	50%	"	"	1750	3182
25%	" "	75%	"	"	1760	3200

No matter what is used as mortar, it should be made as thin as possible, not only to lessen the chances of harmful results arising from the difference in the structure of the joint as compared with the structure of the brick, but to increase the relative proportion of brick to joint, for at no time can the joint be expected to exert a greater resistance to the action of destroying influences than can the brick itself, particularly if the brick has been selected with a view to resisting conditions such as the finished work will meet.

ANALYSES

We never sell our products based on analyses. We furnish below, as a matter of information, typical analyses of our Flint and Plastic Clays. The samples analyzed were not selected but are representative of an entire day's work.

	FLINT	PLASTIC
IGNITION	11.65	8.04
SILICA	51.60	60.64
ALUMINA	34.15	25.77
FERRIC OXIDE	1.17	1.93
LIME	.38	.54
MAGNESIA	.17	.20
ALKALIES	.58	1.46
	99.70	98.58
FUSION:	3128 F. CONE 33	2975°F. CONE 28

The most recent analysis of our "Mount Savage" brick shows:

SILICA	62.32
ALUMINA	31.65
IRON OXIDE	2.30
LIME	0.10
MAGNESIA	0.54
ALKALIES	1.12
TITANIUM OXIDE	2.30
Total	100.33

All the above analyses were made by the Refractories Manufacturers Association's Fellowship at the Mellon Institute of Industrial Research, Pittsburgh, Pa.

WE show on the following pages the 9" and 9" series brick, as well as a number of shapes larger than 9", which have been adopted as standards by the members of the Refractories Manufacturers Association.

Any shape ordered, that is not shown herein will be classed as a special, and price for same will be based accordingly.

We recommend the use of these standards wherever possible, for it will be found that they can be used in many cases where specials are called for. This not only diminishes the cost, but also hastens delivery as standards are usually carried in stock and their initial cost is much less.

STANDARD 9" SHAPES

9" STRAIGHT
9" x 4½" x 2½"

SMALL 9" BRICK
9" x 3½" x 2½"

SPLIT BRICK
9" x 4½" x 1¼"

2" BRICK
9" x 4½" x 2"

SOAP
9" x 2¼" x 2½"

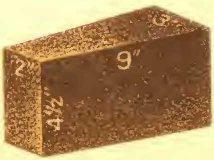
STANDARD 9" SHAPES

CHECKER
9" x 2¾" x 2¾"

No. 1 WEDGE
9" x 4½" x (2½" — 1⅞")

No. 2 WEDGE
9" x 4½" x (2½" — 1½")

No. 3 WEDGE
9" x 4½" x (3" — 2 ")

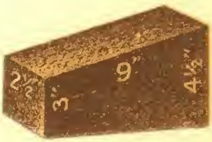


STANDARD 9" SHAPES

No. 1 KEY
9" x (4½" — 4") x 2½"

No. 2 KEY
9" x (4½" — 3½") x 2½"

No. 3 KEY
9" x (4½" — 3") x 2½"



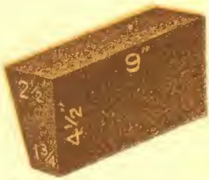
No. 4 KEY
9" x (4½" — 2¼") x 2½"

STANDARD 9" SHAPES

BUNG ARCH
9" x 4½" x (2½"—2⅜")

No. 1 ARCH
9" x 4½" x (2½"— 2⅛")

No. 2 ARCH
9" x 4½" x (2½"— 1¾")



NO. 3 ARCH
9" x 4½" x (2½"— 1")

UNION MINING COMPANY

STANDARD 9" SHAPES

JAMB BRICK
9" x 4½" x 2½"

No. 1 NECK
9" x 4½" x 3½" x 2½" x ⅝"

No. 2 NECK
9" x 4½" x 2½" x 1½" x ⅝"

NO. 3 NECK
9" X 4½" X (2½"—⅝")

STANDARD 9" SHAPES

END SKEW
(9" — 6¾") x 4½" x 2½"

SIDE SKEW
9" x (4½" — 2¼") x 2½"

EDGE SKEW
9" x (4½" — 1½") x 2½"

FEATHER EDGE
9" x 4½" x (2½" — ⅛")

UNION MINING COMPANY

STANDARD 9" SHAPES

CIRCLE BRICK

CIRCLE BRICK

Name	Dimensions	Diameter Ins.	Diameter Outs.	No. of Brick to Circle
24" Circle	(9"—6 17/32") x 4½" x 2½"	24"	33"	12
36" "	(9"—7 3/16") x 4½" x 2½"	36"	45"	16
48" "	(9"—7 17/32") x 4½" x 2½"	48"	57"	20
60" "	(9"—7 13/16") x 4½" x 2½"	60"	69"	24
72" "	(9"—8") x 4½" x 2½"	72"	81"	28
84" "	(9"—8⅛") x 4½" x 2½"	84"	93"	32

STANDARD SHAPES
LARGER THAN 9 INCH

UNION MINING COMPANY

STANDARD SHAPES

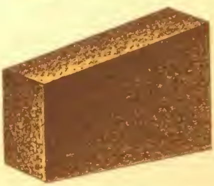
9" x 4½" x 3"
STRAIGHT

9" x(6" x 2½")STRAIGHT
(FLAT BACK STRAIGHT)
ALSO 9"x(6" x 3")

FLAT BACK ARCH
9"x 6" x (3⅛" — 2⅛")

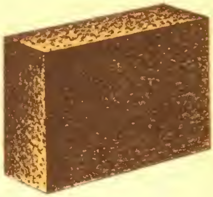
9" x6" No. 1 KEY
FOR 13' CIRCLE (INSIDE DIAMETER)
91 BRICK TO THE CIRCLE
9" x (6"—5⅜") x 2½"
ALSO (9" x 6"—5⅜") x 3"

9" x 6" No. 2 KEY
FOR 6' CIRCLE (INSIDE DIAMETER)
47 BRICK TO THE CIRCLE
9" x (6"—4 13/16") x 2½"
ALSO 9" x (6"—4 13/16") x 3"



STANDARD SHAPES

LARGE 9"
9" x 6¾" x 2½"

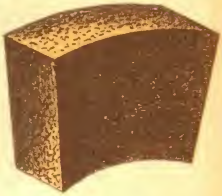


LARGE 9" No. 1 WEDGE
9" x 6¾" x (2½" — 1⅞")

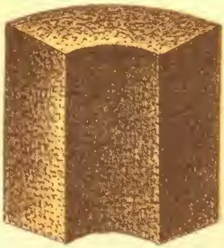
LARGE 9" No. 2 WEDGE
9" x 6¾" x (2½" — 1½")

STANDARD SHAPES

No. of Block	Dimensions	Diameter Ins.	Diameter Outs.	No. Brick to Circle
30	(9″—6 7/16″) x 6″ x 4″	30″	42″	15
36	(9″—6 3/4″) x 6″ x 4″	36″	48″	17
42	(9″—7″) x 6″ x 4″	42″	54″	19
48	(9″—7 3/16″) x 6″ x 4″	48″	60″	21
54	(9″—7 3/8″) x 6″ x 4″	54″	66″	23
60	(9″—7 1/2″) x 6″ x 4″	60″	72″	25
66	(9″—7 5/8″) x 6″ x 4″	66″	78″	27
72	(9″—7 23/32″) x 6″ x 4″	72″	84″	29
78	(9″—7 13/16″) x 6″ x 4″	78″	90″	31
84	(9″—7 7/8″) x 6″ x 4″	84″	96″	33
90	(9″—7 15/16″) x 6″ x 4″	90″	102″	36
96	(9″—8″) x 6″ x 4″	96″	108″	38
102	(9″—8 1/16″) x 6″ x 4″	102″	114″	40
108	(9″—8 1/8″) x 6″ x 4″	108″	120″	42



CUPOLA AND ROTARY KILN BLOCKS
(9″ —) x 6″ x 4″

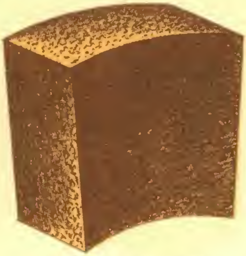


CUPOLA BLOCKS
(9″ —) x 4 1/2″ x 9″

No. of Block	Dimensions	Diameter Ins.	Diameter Outs.	No. of Brick to Circle
A	(9″—5 3/4″) x 4 1/2″ x 9″	16″	25″	9
B	(9″—6 5/16″) x 4 1/2″ x 9″	21″	30″	11
C	(9″—6 3/4″) x 4 1/2″ x 9″	27″	36″	13
D	(9″—6 15/16″) x 4 1/2″ x 9″	30″	39″	14
E	(9″—7 11/32″) x 4 1/2″ x 9″	40″	49″	17
F	(9″—7 21/32″) x 4 1/2″ x 9″	51″	60″	21
G	(9″—7 13/16″) x 4 1/2″ x 9″	60″	69″	24
H	(9″—8″) x 4 1/2″ x 9″	73″	82″	29

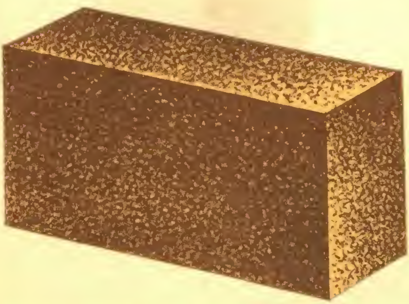
UNION MINING COMPANY

STANDARD SHAPES



(9″ —) x 9″ x 4″
ROTARY KILN BLOCKS

No. of Block	Dimensions	Diameter Ins.	Diameter Puts.	No. of Brick to Circle
48	(9″—6$\frac{17}{32}$″) x 9″ x 4″	48″	66″	23
54	(9″—6$\frac{3}{4}$″) x 9″ x 4″	54″	72″	25
60	(9″—6$\frac{15}{16}$″) x 9″ x 4″	60″	78″	27
66	(9″—7$\frac{1}{16}$″) x 9″ x 4″	66″	84″	29
72	(9″—7$\frac{3}{16}$″) x 9″ x 4″	72″	90″	31
78	(9″—7$\frac{5}{16}$″) x 9″ x 4″	78″	96″	33
84	(9″—7$\frac{13}{32}$″) x 9″ x 4″	84″	102″	36
90	(9″—7$\frac{1}{2}$″) x 9″ x 4″	90″	108″	38
96	(9″—7$\frac{19}{32}$″) x 9″ x 4″	96″	114″	40
102	(9″—7$\frac{21}{32}$″) x 9″ x 4″	102″	120″	42



STOCK HOLE TILE AND BOTTOM BLOCK
18″ x 9″ x 4½″
ALSO 18″ x 12″ x 8″

STANDARD SHAPES

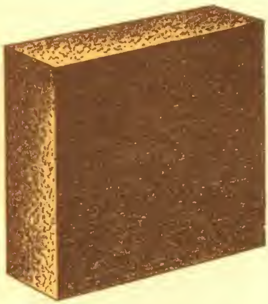
9″ x 9″ STRAIGHT
FOR ENLARGING CIRCLES
9″ x 9″ x 3½″
ALSO 13½″ x 9″ x 3½″

9″ x 9″ ARCH
FOR 3,′ 4,′ 5′ INSIDE DIAMETER
9″ x 9″ x (3½″ —)
ALSO 13½″ x 9″ x (3½″ —)
FOR 3′—9″ x 9″ x (3½″—2¼″)
" 4′—9″ x 9″ x (3½″—2 17/32″)
" 5′—9″ x 9″ x (3½″—2 11/16″)
FOR 3′—13½″ x 9″ x (3½″—2¼″)
" 4′—13½″ x 9″ x (3½″—2 17/32″)
" 5′—13½″ x 9″ x (3½″—2 11/16″)

STANDARD SHAPES

10" x 4½" x 4½"
10½" x 4½" x 4½"
10¾" x 4½" x 4½"

OPEN HEARTH CHECKER



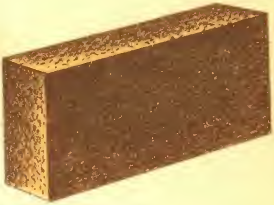
SQUARE EDGE TILE

The following are the standard rectangular tile adopted by the Refractories Manufacturers Association.

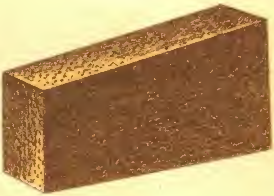
Length	3" Thick 6" Series	3" Thick 9" Series	4" Thick 9" Series	4" Thick 12" Series
18 "	18 x 6 x 3	18 x 9 x 3	18 x 9 x 4	18 x 12 x 4
22½"	22½ x 6 x 3	22½ x 9 x 3	22½ x 9 x 4	22½ x 12 x 4
27 "		27 x 9 x 3	27 x 9 x 4	27 x 12 x 4
31½"				31½ x 12 x 4
36 "				36 x 12 x 4

STANDARD SHAPES

13½″ STRAIGHT
13½″ x 6″ x 2½″
ALSO 13½″ x 6″ x 3″



13½″ No. 1 KEY
13½″ x (6″ — 5″) x 2½″
ALSO 13½″ x (6″ — 5″) x 3″

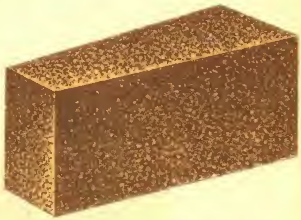


13½″ No. 2 KEY
13½″ x (6″ — 4⅜″) x 2½″
ALSO 13½″ x (6″ — 4⅜″) x 3″

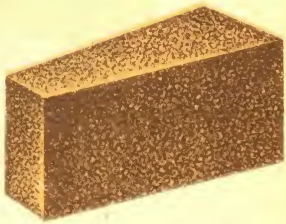
STANDARD SHAPES

BRIDGE BLOCK
13½″ x 6″ x 3″

13½″ No 1 WEDGE
13½″ x 6″ x (3″—2¾″)

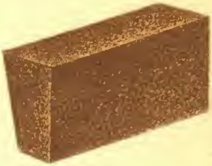


13½″ No. 2 WEDGE
13½″ x 6″ x (3″—2½″)



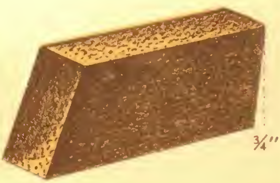
13½″ No 3 WEDGE
13½″ x 6″ x (3″—2″)

STANDARD SHAPES FOR MALLEABLE FURNACES



BUNG ARCH
9″ x 4½″ x (2½″—2⅜″)

No. 101 SQUARE BUNG
13″ x 4⅛″ x 3″

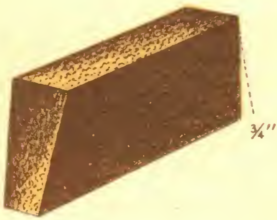


No. 102 ANGLE BUNG
(11⅜″ — 12¾″) x 4½″ x 3″

UNION MINING COMPANY

STANDARD SHAPES FOR MALLEABLE FURNACES

No. 103 ARCH BUNG
13″ x 4½″ x (3″—2⅝″)



No. 104 ARCH ANGLE BUNG
(11⅜″—12¾″) x 4½″ x (3″—2⅝″)

No. 105 ARCH BUNG
13″ x 4½″ x (3″ — 2⅞″)

LIME KILN BRICK

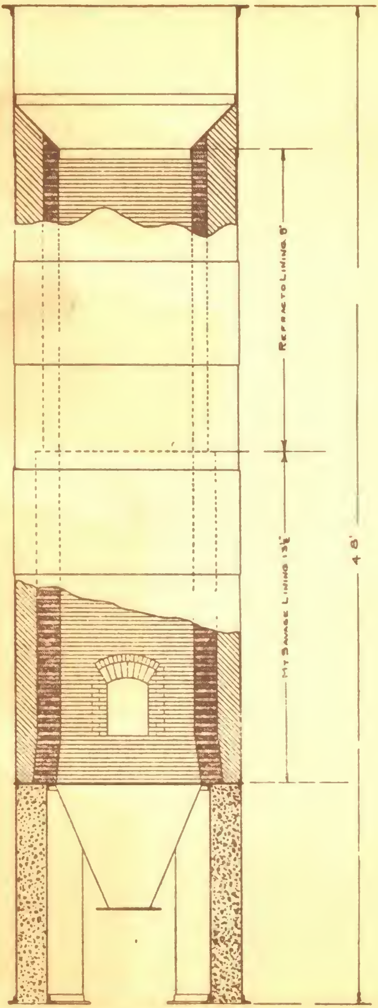
IT is an established fact that the conditions encountered in the burning of lime are such that the average high grade fire brick, as manufactured for general commercial purposes, will not give satisfactory service in lime kilns, and that a brick of special composition, manufacture and burn must be used if the best results are to be obtained.

We have installed machinery which enables us to make from our clays a brick that will withstand the chemical action of the burning stone, as well as the mechanical action of the descending charge; Mount Savage clays having sufficient refractoriness to withstand the intense heat necessary to burn the stone. We vary the proportions of Flint and Plastic Clay in the different brick to enable them to meet the conditions referred to above.

The best results can be expected from using "Mount Savage" for the arches and heat zone, and "Refracto" for the remaining portions of the kiln.

The regular 9" and 13½" series brick are generally used in lining lime kilns. Some types of lime kilns require the special shapes shown on the following page.

We strongly recommend that Mount Savage fire clay be used in the setting of fire brick linings in lime kilns.

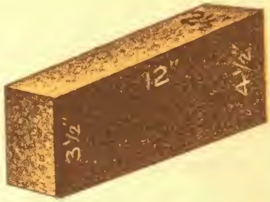


PLAN OF LIME KILN

UNION MINING COMPANY

SPECIAL BRICK FOR LIME KILNS

12-INCH KEY
12″ x (4½″ x 3½″) x 2½″



14-INCH KEY
14″ x (7″ x 6″) x 6″

9-INCH SQUARE
9″ x 9″ x 4″

ARCH

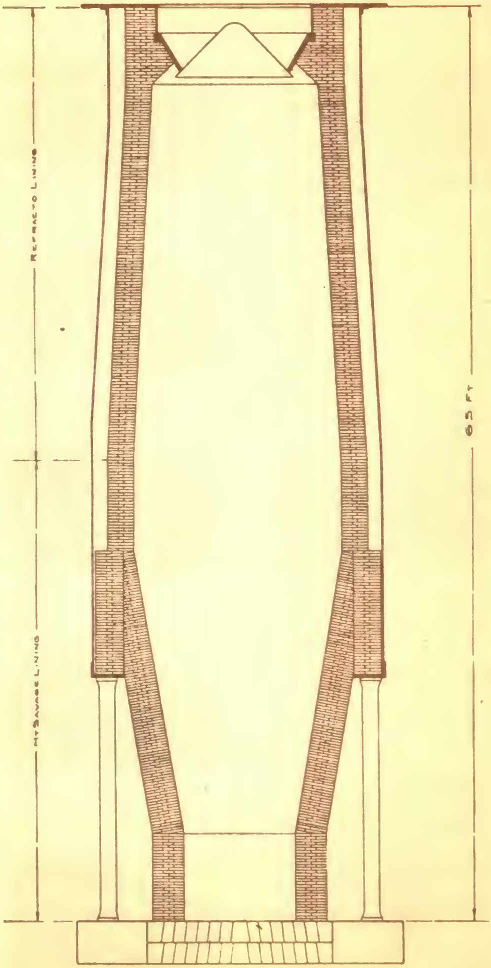
$$\left.\begin{matrix}9''\\12''\\14''\\16''\\18''\end{matrix}\right\}\times 9''\times(4''\times 3'')$$

BLAST FURNACE LININGS

THE conditions existing in modern blast furnaces are extremely severe, combining, as they do, great abrasion, high temperature and reduction. Further, the construction of a furnace is such a costly and important piece of work that only the highest grade of fire brick should be used in the lining. While a brick of fair quality will resist the above mentioned conditions for a limited time, it is only those of the very best quality that will enable the operator to make sufficiently long campaigns to get a maximum tonnage.

We recommend our "Mount Savage" lining be used throughout the furnace. The brick for the hearth and bosh, inwall and top are each made to withstand the conditions encountered in the particular portions of the furnace for which they are intended. They are made by the most approved methods from our "Mount Savage" flint, calcined and plastic clays. Our blast furnace brick are branded "Mount Savage Hearth and Bosh", "Mount Savage Inwall" and "Mount Savage Top".

The best results are always obtained by using our "Mount Savage" screened clay in blast furnace brick work.



PLAN OF BLAST FURNACE

UNION MINING COMPANY

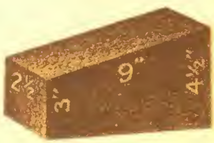
BLAST FURNACE SHAPES

9" STRAIGHT
9" x 4½" x 2½"

No. 1 KEY
9" x (4½" — 4") x 2½"

No. 2 KEY
9" x (4½" — 3½") x 2½"

No. 3 KEY
9" x (4½" — 3") x 2½"



No. 4 KEY
9" x (4½" — 2¼") x 2½"

BLAST FURNACE SHAPES

9″ x 6″ x 2½″ STRAIGHT
ALSO 9″ x 6″ x 3″

9″ x 6″ No. 1 KEY
9″ x (6″ — 5⅜″) x 2½″
ALSO 9″ x (6″ — 5⅜″) x 3″

9″ x 6″ No. 2 KEY
9″ x (6″ — 4 13/16″) x 2½″
ALSO 9″ x (6″ — 4 13/16″) x 3″

BLAST FURNACE SHAPES

13½" STRAIGHT
13½" x 6" x 2½"
ALSO 13½" x 6" x 3"

13½" No. 1 KEY
13½" x (6" — 5") x 2½"
ALSO 13½" x (6" — 5") x 3"

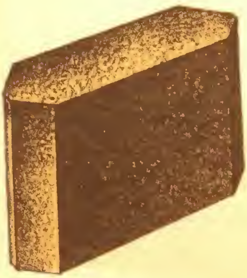
13½" No. 2 KEY
13½" x (6" — 4⅜") x 2½"
ALSO 13½" x (6" — 4⅜") x 3"

TYPICAL HOT BLAST STOVE CHECKER BRICK

12 x 13 INCH HEXAGON
9" DIAMETER FLUE
12" x 7½" x 9"

6 x 13 INCH HEXAGON
FOR BREAKING JOINTS
6" x 7½" x 9"

CHECKER BRICK
FOR WHITE & KERNAN STOVE



CHECKER BRICK
FOR FOOTE STOVE

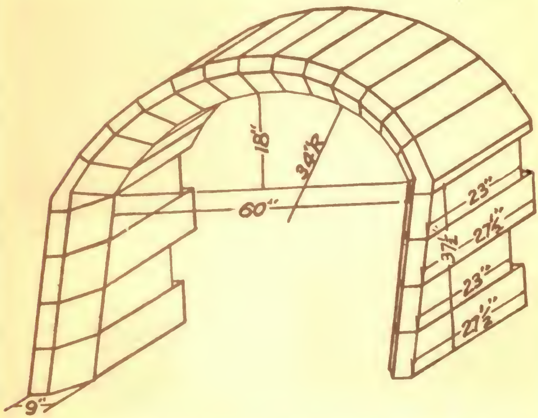
CHECKER BRICK
FOR ROBERTS STOVE

UNION MINING COMPANY

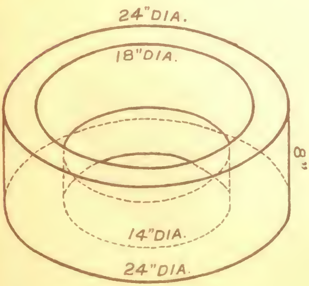
STANDARD SHAPES FOR RECTANGULAR OVENS

AS ADOPTED BY THE MEMBERS OF

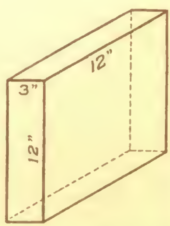
THE REFRACTORIES MANUFACTURERS ASSOCIATION



RECT. OVEN-ARCHES, SKEWS & JAMBS



RECT. OVEN HOPPER



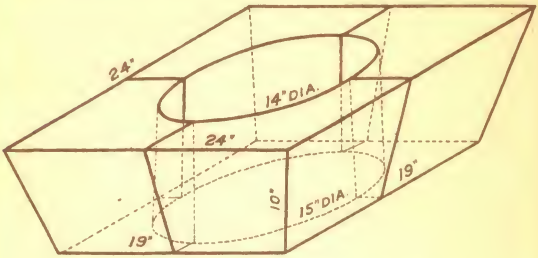
RECT. OVEN BOTTOM TILE

UNION MINING COMPANY

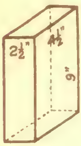
STANDARD SHAPES FOR RECTANGULAR OVENS

AS ADOPTED BY THE MEMBERS OF

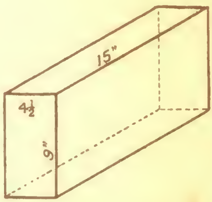
THE REFRACTORIES MANUFACTURERS ASSOCIATION



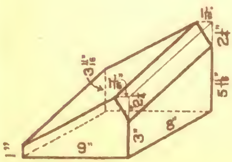
RECT, OVEN—4 PIECE TRUNNEL



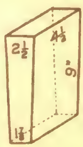
9′ STRAIGHT
FOR RECT. OVEN LINING



RECT. OVEN 15′ LINER BLOCK



RECT. OVEN CROWN SKEW
R—AS SHOWN
L—OPP. HAND



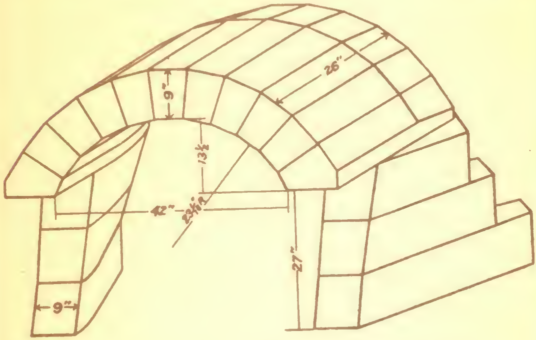
9′ No. 1 WEDGE
FOR RECT. OVEN CROWN

UNION MINING COMPANY

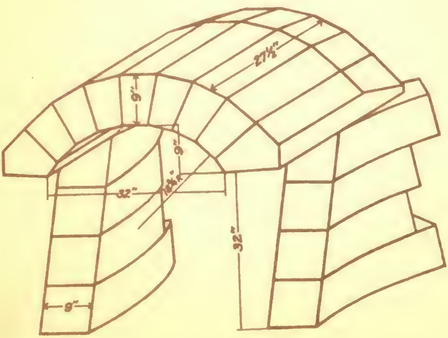
STANDARD SHAPES FOR BEE HIVE OVENS

AS ADOPTED BY THE MEMBERS OF

THE REFRACTORIES MANUFACTURERS ASSOCIATION



BEE HIVE 42' ARCHES, SKEWS & JAMBS
(FOR MACHINE DRAWN OVENS)



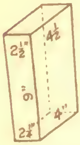
BEE HIVE 32' ARCHES, SKEWS & JAMBS
(FOR HAND DRAWN OVENS)

UNION MINING COMPANY

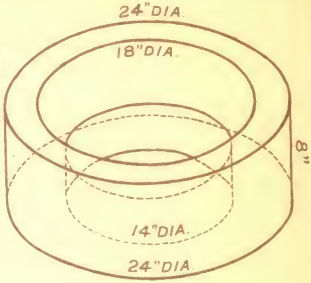
STANDARD SHAPES FOR BEE HIVE OVENS

AS ADOPTED BY THE MEMBERS OF

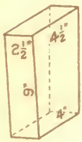
THE REFRACTORIES MANUFACTURERS ASSOCIATION



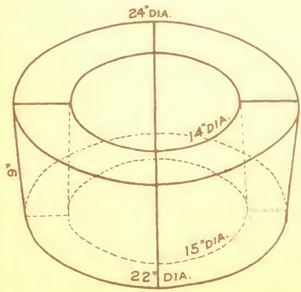
BEE HIVE CROWN



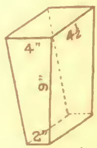
BEE HIVE HOPPER



BEE HIVE LINER



BEE HIVE SOLID OR
4 PIECE TRUNNEL



BEE HIVE BULLHEAD
(FOR WASTE HEAT FLUES)

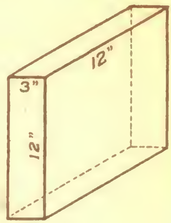
UNION MINING COMPANY

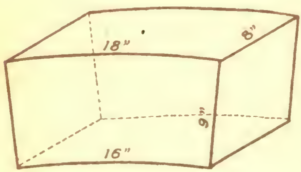
STANDARD SHAPES FOR BEE HIVE OVENS

AS ADOPTED BY THE MEMBERS OF

THE REFRACTORIES MANUFACTURERS ASSOCIATION

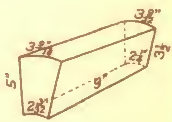
BEE HIVE BOTTOM TILE

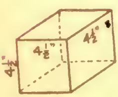




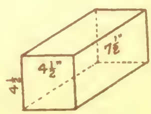
BEE HIVE RING WALL BLOCK

BEE HIVE 14'-21 PIECE
TRUNNEL BLOCK





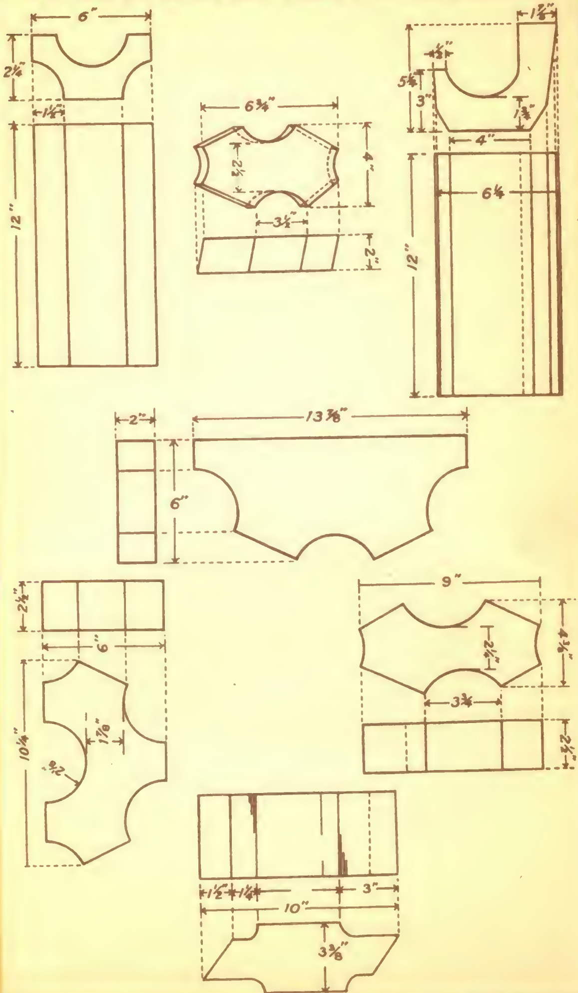
BEE HIVE 4½'
DOOR BLOCK



BEE HIVE 7½'
DOOR BLOCK

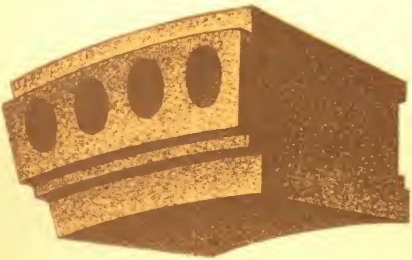
UNION MINING COMPANY

TYPICAL BAFFLE TILE FOR BOILERS



SPECIAL SHAPE BRICK

OUR PLANT is equipped for making practically any special shape that may be required in fire clay material. We show upon this and the following pages, some of the intricate shapes which we are called upon to make.



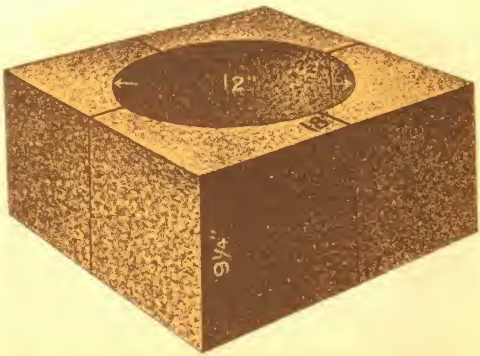
WIRE ANNEALING FURNACE BRICK

The illustration of the perforated arch block for wire annealing furnaces gives a

SPECIAL SHAPE BRICK—*Continued*

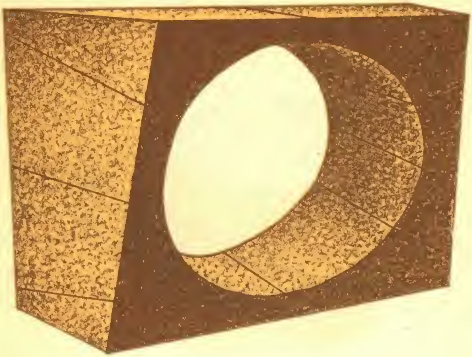
fair idea as to what we can do along this line.

When called upon to furnish special shapes we always endeavor to study the

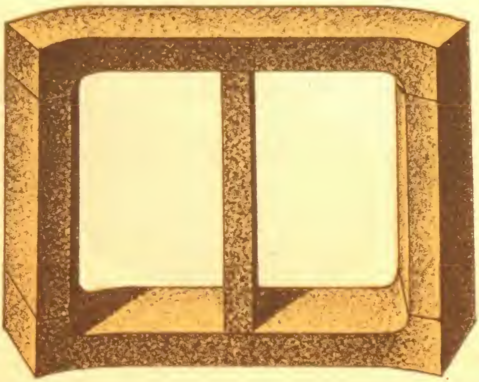


FEED HOLE BRICK FOR DUTCH OVEN
MADE IN ONE, TWO, OR FOUR PIECES, AND IN ANY SIZE DESIRED

SPECIAL SHAPE BRICK—*Continued*



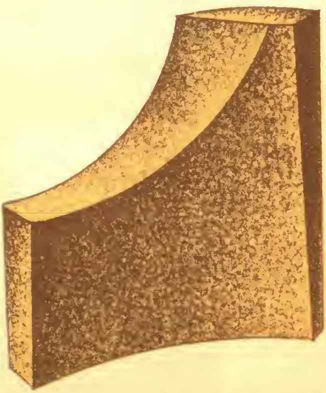
conditions under which they will be used; the fuel, whether oil, gas or coal; the



SPECIAL SHAPE BRICK—*Continued*

material to be worked; the method of operating the furnaces, etc. We then

determine the mixture, grind and burn best adapted to the conditions—with the



result that we are able to furnish special difficult shapes that give superior service.

SPECIAL SHAPE BRICK—*Continued*

No. 1 VELVETRY TILE
25" x (6¾"—4½") x 10"

No. 2 VELVETRY TILE
24" x 4½" x 10"

DOOR BRICK

USEFUL INFORMATION

A nine-inch straight fire brick (9x4½x2½") weighs approximately seven pounds.

All fire brick when stored should be protected from the weather. This particularly applies during the winter season, as moisture, especially in cold weather, will greatly injure any brick.

The minimum car load for brick or clay is 50,000 pounds.

To secure the best results, fire brick should be laid in the same clay as that from which the brick are made. WE LAY GREAT STRESS UPON THIS.

Fire clay should be used as a thin paste and not as mortar. *The thinner the joint the better the wall.*

We grind clay very fine for this purpose and furnish it, either raw or calcined, in bulk or in sacks, in cars with brick or in full car lots.

When ordering linings for cupolas or stacks be careful to give both inside and outside diameters.

All new brick work should be heated very gradually to expel moisture before being subjected to very intense heat.

One cubic foot of wall requires 17 nine-inch brick; one cubic yard requires 460. Where key, wedge and other shapes are used, add 10 per cent. in estimating the required number.

For estimating on fire brick work, use the following figures:

1 square foot 4½-inch wall requires 7 brick.

1 square foot 9-inch wall requires 14 brick.

1 square foot 13½-inch wall requires 21 brick.

1 cubic foot brickwork requires 17 nine-inch straight brick.

1 cubic foot fire clay brickwork weighs 150 pounds.

1 cubic foot silica brickwork weighs 130 pounds.

1,000 brick (closely stacked) occupy 56 cubic feet.

1,000 brick (loosely stacked) occupy 72 cubic feet.

For estimating on red brickwork, figure on nine cubic feet of sand and three bushels of lime for laying 1,000 brick.

UNION MINING COMPANY

TABLE OF 9-INCH ARCH BRICK

Inside Diameter	Shapes Required				
	No. 3 Arch	No. 2 Arch	No. 1 Arch	Straight	Total
0 ft. 6 in.	19	....	....	....	19
1 " 0 "	12	15	....	....	27
1 " 6 "	4	30	....	....	34
1 " 9 "	....	38	....	....	38
2 " 0 "	....	34	8	....	42
2 " 6 "	....	26	23	....	49
3 " 0 "	....	19	38	....	57
3 " 6 "	....	11	53	....	64
4 " 0 "	....	4	68	....	72
4 " 3 "	....	....	76	....	76
4 " 6 "	....	....	76	4	80
5 " 0 "	....	....	76	11	87
5 " 6 "	....	....	76	19	95
6 " 0 "	....	....	76	27	103
6 " 6 "	....	....	76	34	110
7 " 0 "	....	....	76	42	118
7 " 6 "	....	....	76	49	125
8 " 0 "	....	....	76	57	133
8 " 6 "	....	....	76	64	140
9 " 0 "	....	....	76	72	148
9 " 6 "	....	....	76	79	155
10 " 0 "	....	....	76	87	163
10 " 6 "	....	....	76	94	170
11 " 0 "	....	....	76	102	178
11 " 6 "	....	....	76	109	185
12 " 0 "	....	....	76	117	193

TABLE OF 9-INCH WEDGE BRICK

Inside Diameter	Shapes Required			
	No. 2 Wedge	No. 1 Wedge	Straight	Total
2 ft. 3 in.	57	....	....	57
2 " 6 "	49	11	....	60
3 " 0 "	38	30	....	68
3 " 6 "	26	50	....	76
4 " 0 "	12	71	....	83
4 " 6 "	....	91	....	91
5 " 0 "	....	91	8	99
5 " 6 "	....	91	15	106
6 " 0 "	....	91	23	114
6 " 6 "	....	91	30	121
7 " 0 "	....	91	38	129
7 " 6 "	....	91	45	136
8 " 0 "	....	91	53	144
8 " 6 "	....	91	60	151
9 " 0 "	....	91	68	159
9 " 6 "	....	91	76	167
10 " 0 "	....	91	83	174
10 " 6 "	....	91	91	182
11 " 0 "	....	91	98	189
11 " 6 "	....	91	106	197
12 " 0 "	....	91	113	204
12 " 6 "	....	91	121	212

UNION MINING COMPANY

TABLE OF 9-INCH WEDGE BRICK

Inside Diameter	Shapes Required — No. 2 Wedge	(Continued.) No. 1 Wedge	Straight	Total
13 " 0 "	....	91	128	219
13 " 6 "	....	91	136	227
14 " 0 "	....	91	143	234
14 " 6 "	....	91	151	242
15 " 0 "	....	91	158	249
15 " 6 "	....	91	166	257
16 " 0 "	....	91	173	264
16 " 6 "	....	91	181	272
17 " 0 "	....	91	188	279
17 " 6 "	....	91	196	287
18 " 0 "	....	91	203	294
18 " 6 "	....	91	211	302
19 " 0 "	....	91	218	309
19 " 6 "	....	91	226	317
20 " 0 "	....	91	233	324
20 " 6 "	....	91	241	332
21 " 0 "	....	91	248	339
21 " 6 "	....	91	256	347
22 " 0 "	....	91	263	354
22 " 6 "	....	91	271	362
23 " 0 "	....	91	278	369
23 " 6 "	....	91	286	377
24 " 0 "	....	91	293	384
24 " 6 "	....	91	301	392
25 " 0 "	....	91	308	399
25 " 6 "	....	91	316	407
26 " 0 "	....	91	323	414
26 " 6 "	....	91	331	422
27 " 0 "	....	91	338	429
27 " 6 "	....	91	346	437

TABLE OF 9-INCH KEY BRICK

Inside Diameter	Shapes Required — No. 4 Key	No. 3 Key	No. 2 Key	No. 1 Key	Straight	Total
1 ft. 6 in.	25	......	......	......	....	25
2 " 0 "	16	13	......	......	....	29
2 " 6 "	9	25	......	......	....	34
3 " 0 "	......	38	......	......	....	38
3 ft. 6 in.	......	29	13	......	....	42
4 " 0 "	......	21	25	......	....	46
4 " 6 "	......	12	38	......	....	50
5 " 0 "	......	5	50	......	....	55
5 " 3 "	......	......	57	......	....	57
5 " 6 "	......	......	55	4	....	59
6 " 0 "	......	......	50	13	....	63
6 " 6 "	......	......	46	21	....	67
7 " 0 "	......	......	42	29	....	71
7 " 6 "	......	......	38	38	....	76
8 " 0 "	......	......	34	46	....	80
8 " 6 "	......	......	29	55	....	84
9 " 0 "	......	......	25	63	....	88
9 " 6 "	......	......	21	71	....	92

TABLE OF 9-INCH KEY BRICK

Inside Diameter	Shapes Required (Continued.)					
	No 4 Key	No. 3 Key	No 2 Key	No. 1 Key	Straight	Total
10 " 0 "	......	......	17	80	....	97
10 " 6 "	......	......	13	88	....	101
11 " 0 "	......	......	9	96	....	105
11 " 6 "	......	......	4	105	....	109
12 " 0 "	......	......	......	113	....	113
12 " 6 "	......	......	......	113	4	117
13 " 0 "	......	......	......	113	9	122
13 " 6 "	......	......	......	113	13	126
14 " 0 "	......	......	......	113	17	130
14 " 6 "	......	......	......	113	21	134
15 " 0 "	......	......	......	113	25	138
15 " 6 "	......	......	......	113	30	143
16 " 0 "	......	......	......	113	34	147
16 " 6 "	......	......	......	113	38	151
17 " 0 "	......	......	......	113	42	155
17 " 6 "	......	......	......	113	46	159
18 " 0 "	......	......	......	113	50	163
18 " 6 "	......	......	......	113	55	168
19 " 0 "	......	......	......	113	59	172
19 " 6 "	......	......	......	113	63	176
20 " 0 "	......	......	......	113	67	180
20 " 6 "	......	......	......	113	71	184
21 " 0 "	......	......	......	113	76	189
21 " 6 "	......	......	......	113	80	193
22 " 0 "	......	......	......	113	84	197
22 " 6 "	......	......	......	113	88	201
23 " 0 "	......	......	......	113	92	205
23 " 6 "	......	......	......	113	97	210
24 " 0 "	......	......	......	113	101	214
24 " 6 "	......	......	......	113	105	218
25 " 0 "	......	......	......	113	109	222
25 " 6 "	......	......	......	113	113	226
26 " 0 "	......	......	......	113	117	230
26 " 6 "	......	......	......	113	122	235
27 " 0 "	......	......	......	113	126	239
27 " 6 "	......	......	......	113	130	243
28 " 0 "	......	......	......	113	134	247
28 " 6 "	......	......	......	113	138	251
29 " 0 "	......	......	......	113	143	256
29 " 6 "	......	......	......	113	147	260
30 " 0 "	......	......	......	113	151	264
30 " 6 "	......	......	......	113	155	268
31 " 0 "	......	......	......	113	159	272
31 " 6 "	......	......	......	113	163	276
32 " 0 "	......	......	......	113	168	281
32 " 6 "	......	......	......	113	172	285
33 " 0 "	......	......	......	113	176	289
33 " 6 "	......	......	......	113	180	293
34 " 0 "	......	......	......	113	184	297
34 " 6 "	......	......	......	113	189	302
35 " 0 "	......	......	......	113	193	306

TABLE OF 9X6X3-INCH KEY BRICK

Inside Diameter	Shapes Required			
	No. 2 Key $9x(6\text{-}4\frac{13}{16})x3$	No. 1 Key $9x\ 6\text{-}5\frac{3}{8}\ x3$	Squares	Total
6 ft. 0 in.	47	....	....	47
6 " 6 "	44	6	....	50
7 " 0 "	42	12	....	54
7 " 6 "	38	19	....	57
8 " 0 "	34	26	....	60
8 " 6 "	31	32	....	63
9 " 0 "	27	39	....	66
9 " 6 "	23	46	....	69
10 " 0 "	20	52	....	72
10 " 6 "	16	59	....	75
11 " 0 "	13	66	....	79
11 " 6 "	10	72	....	82
12 " 0 "	6	79	....	85
12 " 6 "	3	85	....	88
13 " 0 "	....	91	....	91
13 " 6 "	....	91	3	94
14 " 0 "	....	91	6	97
14 " 6 "	....	91	10	101
15 " 0 "	....	91	13	104
15 " 6 "	....	91	16	107
16 " 0 "	....	91	19	110
16 " 6 "	....	91	22	113
17 " 0 "	....	91	25	116
17 " 6 "	....	91	28	119
18 " 0 "	....	91	32	123
18 " 6 "	....	91	35	126
19 " 0 "	....	91	38	129
19 " 6 "	....	91	41	132
20 " 0 "	....	91	44	135
20 " 6 "	....	91	47	138
21 " 0 "	....	91	50	141
21 " 6 "	....	91	54	145
22 " 0 "	....	91	57	148
22 " 6 "	....	91	60	151
23 " 0 "	....	91	63	154
23 " 6 "	....	91	66	157
24 " 0 "	....	91	69	160
24 " 6 "	....	91	72	163
25 " 0 "	....	91	76	167
25 " 6 "	....	91	79	170
26 " 0 "	....	91	82	173
26 " 6 "	....	91	85	176
27 " 0 "	....	91	88	179
27 " 6 "	....	91	91	182
28 " 0 "	....	91	94	185
28 " 6 "	....	91	98	189
29 " 0 "	....	91	101	192
29 " 6 "	....	91	104	195
30 " 0 "	....	91	107	198

TABLE OF 13½-INCH KEY BRICK

Inside Diameter	Shapes Required			
	No. 2 Key	No. 1 Key	Straight	Total
6 ft. 0 in.	52	....	....	52
6 " 6 "	48	7	....	55
7 " 0 "	42	16	....	58
7 " 6 "	37	24	....	61
8 " 0 "	33	32	....	65
8 " 6 "	28	40	....	68
9 " 0 "	23	48	....	71
9 " 6 "	18	56	....	74
10 " 0 "	12	65	....	77
10 " 6 "	7	73	....	80
11 " 0 "	2	81	....	83
11 " 3 "	....	85	....	85
11 " 6 "	....	85	2	87
12 " 0 "	....	85	5	90
12 " 6 "	....	85	8	93
13 " 0 "	....	85	11	96
13 " 6 "	....	85	14	99
14 " 0 "	....	85	17	102
14 " 6 "	....	85	21	106
15 " 0 "	....	85	24	109
15 " 6 "	....	85	27	112
16 " 0 "	....	85	30	115
16 " 6 "	....	85	33	118
17 " 0 "	....	85	36	121
17 " 6 "	....	85	39	124
18 " 0 "	....	85	43	128
18 " 6 "	....	85	46	131
19 " 0 "	....	85	49	134
19 " 6 "	....	85	52	137
20 " 0 "	....	85	55	140
20 " 6 "	....	85	58	143
21 " 0 "	....	85	61	146
21 " 6 "	....	85	65	150
22 " 0 "	....	85	68	153
22 " 6 "	....	85	71	156
23 " 0 "	....	85	74	159
23 " 6 "	....	85	77	162
24 " 0 "	....	85	80	165
24 " 6 "	....	85	83	168
25 " 0 "	....	85	87	172
25 " 6 "	....	85	90	175
26 " 0 "	....	85	93	178
26 " 6 "	....	85	96	181
27 " 0 "	....	85	99	184
27 " 6 "	....	85	102	187
28 " 0 "	....	85	105	190
28 " 6 "	....	85	109	194
29 " 0 "	....	85	112	197
29 " 6 "	....	85	115	200
30 " 0 "	....	85	118	203
30 " 6 "	....	85	121	206
31 " 0 "	....	85	124	209

TABLE OF 13½ - INCH KEY BRICK

Inside Diameter	Shapes Required: No. 2 Key	No. 1 Key	Straight	(Continued) Total
31 " 6 "	... .	85	127	212
32 " 0 "	....	85	131	216
32 " 6 "	....	85	134	219
33 " 0 "	....	85	137	222
33 " 6 "	....	85	140	225
34 " 0 "	....	85	143	228
34 " 6 "	....	85	146	231
35 " 0 "	....	85	149	234

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TABLE OF 13½" WEDGE BRICK

Inside Diameter	Shapes Required: No. 3 Wedge 13½"x 6"x3" x2"	No. 2 Wedge 13½"x 6"x3" x2½"	No. 1 Wedge 13½"x 6"x3" x2¾"	Straight 13½"x6" x3"	Total
4 ft. 6 in.	85	....	....	....	85
5 " 0 "	79	13	....	....	92
5 " 6 "	73	25	....	....	98
6 " 0 "	66	38	....	....	104
6 " 6 "	60	50	....	....	110
7 " 0 "	54	63	....	....	117
7 " 6 "	47	76	....	....	123
8 " 0 "	41	88	....	....	129
8 " 6 "	35	101	....	....	136
9 " 0 "	29	113	....	....	142
9 " 6 "	22	126	....	....	148
10 " 0 "	16	138	....	....	154
10 " 6 "	10	151	....	....	161
11 " 0 "	3	164	....	....	167
11 " 3 "	....	170	....	....	170
11 " 6 "	....	167	6	....	173
12 " 0 "	....	160	19	....	179
12 " 6 "	....	154	32	....	186
13 " 0 "	....	148	44	....	192
13 " 6 "	....	141	57	....	198
14 " 0 "	....	135	69	....	204
14 " 6 "	....	129	82	....	211
15 " 0 "	....	123	94	....	217
15 " 6 "	....	116	107	....	223
16 " 0 "	....	110	120	....	230
16 " 6 "	....	104	132	....	236
17 " 0 "	....	97	145	....	242
17 " 6 "	....	91	157	....	248
18 " 0 "	....	85	170	....	255
18 " 6 "	....	79	182	....	261
19 " 0 "	....	72	195	....	267
19 " 6 "	....	66	208	....	274
20 " 0 "	....	60	220	....	280
20 " 6 "	....	54	232	....	286
21 " 0 "	....	47	245	....	292
21 " 6 "	....	41	258	....	299
22 " 0 "	....	35	270	....	305
22 " 6 "	....	28	283	....	311
23 " 0 "	....	22	295	....	317
23 " 6 "	....	16	308	....	324
24 " 0 "	....	10	320	....	330
24 " 6 "	....	4	333	....	337
24 " 9 "	....	....	340	....	340
25 " 0 "	....	....	340	3	343
25 " 6 "	....	....	340	9	349

TABLE OF 13½" WEDGE BRICK

Inside Diameter	Shapes Required			(Continued.)	
	No. 3 Wedge 13½"x 6"x3" x2"	No. 2 Wedge 13½"x 6"x3" x2½"	No. 1 Wedge 13½"x 6"x3" x2¾"	Straight 13½"x6" x3"	Total
26 " 0 "	....	....	340	15	355
26 " 6 "	....	....	340	22	362
27 " 0 "	....	....	340	28	368
27 " 6 "	....	....	340	35	375
28 " 0 "	....	....	340	41	381
28 " 6 "	....	....	340	47	387
29 " 0 "	....	....	340	53	393
29 " 6 "	....	....	340	60	400
30 " 0 "	....	....	340	66	406
30 " 6 "	....	....	340	72	412
31 " 0 "	....	....	340	79	419
31 " 6 "	....	....	340	85	425
32 " 0 "	....	....	340	91	431
32 " 6 "	....	....	340	97	437
33 " 0 "	....	....	340	104	444
33 " 6 "	....	....	340	110	450
34 " 0 "	....	....	340	116	456
34 " 6 "	....	....	340	122	462
35 " 0 "	....	....	340	129	469
35 " 6 "	....	....	340	135	475
36 " 0 "	....	....	340	141	481
36 " 6 "	....	....	340	147	487
37 " 0 "	....	....	340	154	494
37 " 6 "	....	....	340	160	500
38 " 0 "	....	....	340	167	507
38 " 6 "	....	....	340	173	513
39 " 0 "	....	....	340	179	519
39 " 6 "	....	....	340	185	525
40 " 0 "	....	....	340	192	532
40 " 6 "	....	....	340	198	538
41 " 0 "	....	....	340	204	544
41 " 6 "	....	....	340	211	551
42 " 0 "	....	....	340	217	557
42 " 6 "	....	....	340	223	563
43 " 0 "	....	....	340	229	569
43 " 6 "	....	....	340	236	576
44 " 0 "	....	....	340	242	582
44 " 6 "	....	....	340	248	588
45 " 0 "	....	....	340	255	595
45 " 6 "	....	....	340	261	601
46 " 0 "	....	....	340	267	607
46 " 6 "	....	....	340	273	613
47 " 0 "	....	....	340	280	620
47 " 6 "	....	....	340	286	626
48 " 0 "	....	....	340	292	632

TABLE OF STANDARD 9″ CIRCLE BRICK

Inside Diameter	Shapes Required					
	24-inch Circle	36-inch Circle	48-inch Circle	60-inch Circle	72-inch Circle	84-inch Circle
2 ft. 0 in.	12					
2 " 3 "	9	4				
2 " 6 "	6	8				
2 " 9 "	3	12				
3 " 0 "		16				
3 " 3 "		11	6			
3 " 6 "		7	11			
3 " 9 "		3	16			
4 " 0 "			20			
4 " 3 "			14	7		
4 " 6 "			9	18		
4 " 9 "			4	19		
5 " 0 "				24		
5 " 3 "				17	8	
5 " 6 "				11	15	
5 " 9 "				5	22	
6 " 0 "					28	
6 " 3 "					21	8
6 " 6 "					14	16
6 " 9 "					7	24
7 " 0 "						32

TABLE OF 6″ CUPOLA BLOCKS

Inside Diameter Cupola Lining	Shapes Required							
	30 in.	36 in.	42 in.	48 in.	54 in.	60 in.	66 in.	72 in.
2 ft. 6 in.	15							
2 " 9 "	8	8						
3 " 0 "		17						
3 " 3 "		9	9					
3 " 6 "			19					
3 " 9 "			9	11				
4 " 0 "				21				
4 " 3 "				10	12			
4 " 6 "					23			
4 " 9 "					12	12		
5 " 0 "						25		
5 " 3 "						13	13	
5 " 6 "							27	
5 " 9 "							15	13
6 " 0 "								29

TABLE OF 6″ CUPOLA BLOCKS

Inside Diameter Cupola Lining	Shapes Required (Continued.)				
	72 in.	78 in	84 in.	90 in.	96 in.
6 ft. 3 in.	17	13	....	....	....
6 " 6 "	....	31	....	....	....
6 " 9 "	....	18	14	....	....
7 " 0 "	....	....	33	....	....
7 " 3 "	....	....	16	19	....
7 " 6 "	....	....	....	36	....
7 " 9 "	....	....	....	17	20
8 " 0 "	....	....	....	....	38

TABLE OF 4½″ CUPOLA BLOCKS

Inside Diameter Cupola Lining	Shapes Required							
	A	B	C	D	E	F	G	H
1 ft. 4 in.	9	....	....	....	....	....	....	....
1 " 6 "	6	4	....	....	....	....	....	....
1 " 9 "	....	11	....	....	....	....	....	....
2 " 0 "	....	6	6	....	...	....	....	....
2 " 3 "	....	....	13	....	....	....	....	....
2 " 6 "	....	....	....	14	....	....	....	....
3 " 0 "	....	....	....	6	10	....	...	....
3 " 4 "	....	....	....	....	17	....	....	....
3 " 6 "	....	....	....	....	14	4	....	....
4 " 0 "	....	....	....	....	5	15	....	....
4 " 3 "	....	....	....	....	....	21	....	....
4 " 6 "	....	....	....	....	....	20	2	....
5 " 0 "	....	....	....	....	....	....	24	...
5 " 6 "	....	....	....	....	....	....	13	13
6 " 0 "	....	....	....	....	....	....	2	27
6 " 1 "	....	....	....	....	....	....	...	29

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TABLE FOR CIRCLE BRICK

For Length of Chord Multiply Sine by Diameter

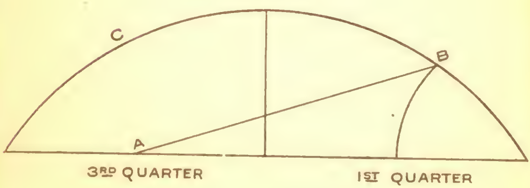
No. to Circle	Sine of Half Angle	Diameter for 9" Chord	No. to Circle	Sine of Half Angle	Diameter for 9" Chord
5	.58779	15.311"	28	.11196	80.385"
6	.50000	18.000"	29	.10811	83.248'
7	.43386	20.740"	30	.10453	86.099"
8	.38268	23.518"	31	.10044	89.605"
9	.34202	26.314"	32	.09802	91.818"
10	.30902	29.124"	33	.09507	94.667"
11	.28173	31.945"	34	.09225	97.560"
12	.25882	34.773"	35	.08965	100.390"
13	.23932	37.606"	36	.08716	103.257"
14	.22251	40.447"	37	.08481	106.119"
15	.20791	43.287"	38	.08258	108.985"
16	.19509	46.132"	39	.08046	111.856"
17	.18428	48.833"	40	.07846	114.708"
18	.17365	51.828"	41	.07655	117.570"
19	.16459	54.681"	42	.07472	120.449"
20	.15643	57.533"	43	.07300	123.287"
21	.14904	60.386"	44	.07136	127.102"
22	.14230	63.246"	45	.06976	129.014"
23	.13617	66.094"	46	.06825	131.868"
24	.13053	68.949"	47	.06679	134.750"
25	.12534	71.805"	48	.06540	137.614"
26	.12054	74.664"	49	.06407	140.471"
27	.11609	77.526"	50	.06279	143.334"

How to Find Number of Inches in Arc, Given Span and Spring of Each

Divide the chord into 4 equal parts; with one extremity as a center, take distance to first quarter as radius and intersect the arc.

The distance from this intersection to the third quarter of chord is equal to ½ the length of the arc.

Example

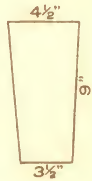


The line A-B is equal to ½ of the arc C

How to Find Diameter of Circle, Given Size of Brick

Multiply length of brick by 2; multiply this product by size of brick on small end, then divide by the difference between large and small ends of brick.

Example



To find diameter of circle this key brick will turn:

Length, or 9 in. x 2=18

18 x 3½=63

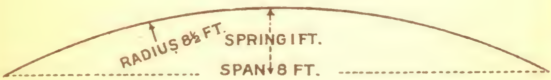
63 divided by difference between

large and small ends—$\begin{array}{r}4\frac{1}{2}\\3\frac{1}{2}\\\hline 1\end{array}$=63 in. or diameter

How to Find Radius of Circle, Given Span and Spring of Arch

To square of ½ of span, divided by spring, add the spring and divide by 2: result is the radius of circle.

Example



Span—8 ft.—
Spring—1 ft.— To find radius:

½ of 8=4,—squared=16
16 divided by spring, or 1=16
add spring 1
———
17
divide by 2=8½ or radius.

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NUMBER OF FIRE BRICK REQUIRED FOR ONE COURSE OF AN ARCH, 4½ INCHES THICK OF VARIOUS SPANS AND SPRINGS

Spring	SPAN				
	2 Ft.	2 Ft. 6 In.	3 Ft.	3 Ft. 6 In.	4 Ft.
3-in.	1 No. 2 Arch 11 No. 1 Arch 25⅛'' Radius 25'' in Arc	11 No. 1 Arch 3 Square 39'' Radius 31'' in Arc			
6-in.	8 No. 2 Arch 6 No. 1 Arch 15'' Radius 28'' in Arc	9 No. 2 Arch 5 Square 21¾'' Radius 33'' in Arc	16 No. 1 Arch 2 Square 30'' Radius 39'' in Arc	13 No. 1 Arch 7 Square 39¾'' Radius 45'' in Arc	12 No. 1 Arch 10 Square 51'' Radius 50'' in Arc
9-in.	16 No. 2 Arch 2 Square 12⅛'' Radius 32'' in Arc	13 No. 2 Arch 6 Square 17'' Radius 37'' in Arc	11 No. 2 Arch 9 Square 22⅛'' Radius 42'' in Arc	10 No. 2 Arch 12 Square 29'' Radius 47'' in Arc	9 No. 2 Arch 15 Square 36⅛'' Radius 53'' in Arc
12-in.			14 No. 2 Arch 9 Square 19⅛'' Radius 46'' in Arc	13 No. 2 Arch 12 Square 24⅜'' Radius 51'' in Arc	11 No. 2 Arch 9 Squares 30'' Radius 56'' in Arc
15-in.					13 No. 2 Arch 15 Square 26¾'' Radius 60'' in Arc

NUMBER OF FIRE BRICK REQUIRED FOR ONE COURSE OF AN ARCH 9 INCHES THICK OF VARIOUS SPANS AND SPRINGS.

Spring	SPAN		
	4 Ft. 6 In.	5 Ft.	5 Ft. 6 In.
6-in.	12 No. 1 Wedge 13 Square 63¾″ Radius 56″ in Arc		
8-in.		15 No. 1 Wedge 14 Square 60″ Radius 63″ in Arc	14 No. 1 Wedge 17 Square 72″ Radius 69″ in Arc
9-in.	18 No. 1 Wedge 10 Square 45″ Radius 58″ in Arc		
10-in.		19 No. 1 Wedge 12 Square 50″ Radius 65″ in Arc	18 No. 1 Wedge 15 Square 59½″ Radius 71″ in Arc
12-in.	23 No. 1 Wedge 7 Square 36⅞″ Radius 61″ in Arc	22 No. 1 Wedge 10 Square 43½″ Radius 67″ in Arc	20 No. 1 Wedge 14 Square 51⅝″ Radius 73″ in Arc
15-in.	5 Square 28 No. 1 Wedge 32″ Radius 65″ in Arc	26 No. 1 Wedge 9 Square 37½″ Radius 70″ in Arc	26 No. 1 Wedge 11 Square 43¾″ Radius 76″ in Arc
18-in.	8 Square 28 No. 1 Wedge 29½″ Radius 69″ in Arc		
20-in.		5 Square 34 No. 1 Wedge 32½″ Radius 76″ in Arc	8 Square 33 No. 1 Wedge 37½″ Radius 81″ in Arc

UNION MINING COMPANY

NUMBER OF FIRE BRICK REQUIRED FOR ONE COURSE OF AN ARCH 9 INCHES THICK OF VARIOUS SPANS AND SPRINGS

Spring	SPAN			
	6 Ft.	6 Ft. 6 In.	7 Ft.	7 Ft. 6 In.
8-in.	9 No. 1 Wedge 24 Square 85'' Radius 74'' in Arc	11 No. 1 Wedge 24 Square 100'' Radius 80'' in Arc	10 No. 1 Wedge 27 Square 114'' Radius 86'' in Arc	
10-in.	15 No. 1 Wedge 29 Square 70'' Radius 76'' in Arc	14 No. 1 Wedge 22 Square 81'' Radius 82'' in Arc	14 No. 1 Wedge 23 Square 93½'' Radius 88'' in Arc	13 No. 1 Wedge 28 Square 106'' Radius 94'' in Arc
12-in.	18 No. 1 Wedge 18 Square 60'' Radius 78'' in Arc	18 No. 1 Wedge 20 Square 69½'' Radius 84'' in Arc	16 No. 1 Wedge 24 Square 80'' Radius 89'' in. Arc	15 No. 1 Wedge 27 Square 91'' Radius 96'' in Arc
15-in.	23 No. 1 Wedge 15 Square 50¾'' in Radius 81'' in Arc	22 No. 1 Wedge 18 Square 58¼'' Radius 86'' in Arc	20 No. 1 Wedge 22 Square 66¾'' Radius 92'' in Arc	19 No. 1 Wedge 25 Square 75'' Radius 98'' in Arc
20-in.	29 No. 1 Wedge 13 Square 42½'' Radius 87'' in Arc	27 No. 1 Wedge 17 Square 48'' Radius 92'' in. Arc	26 No. 1 Wedge 20 Square 54¼'' Radius 97'' in Arc	24 No. 1 Wedge 23 Square 60½'' Radius 103'' in Arc
25-in.				29 No. 1 Wedge 22 Square 52¾'' Radius 109'' in. Arc

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NUMBER OF FIRE BRICK REQUIRED FOR ONE COURSE OF AN ARCH 9 INCHES THICK OF VARIOUS SPANS AND SPRINGS

Spring	SPAN			
	8 Ft.	8 Ft. 6 In.	9 Ft.	9 Ft. 6 In,
10-in.	9 No. 1 Wedge 34 Square 120" Radius 99" in Arc	11 No. 1 Wedge 24 Square 135½" Radius 105" in Arc	10 No. 1 Wedge 27 Square 150½" Radius 111" in Arc	10 No. 1 Wedge 29 Square 167" Radius 117" in Arc
12-in.	14 No. 1 Wedge 30 Square 102" Radius 101" in Arc	14 No. 1 Wedge 32 Square 114" Radius 106" in Arc	14 No. 1 Wedge 35 Square 127½" Radius 112" in Arc	12 No. 1 Wedge 38 Square 141½" Radius 118" in Arc
15-in.	18 No. 1 Wedge 28 Square 84" Radius 103" in Arc	18 No. 1 Wedge 30 Square 94½" Radius 109" in Arc	16 No. 1 Wedge 34 Square 104¾" Radius 115" in Arc	15 No. 1 Wedge 37 Square 116" Radius 121" in Arc
20-in.	23 No. 1 Wedge 26 Square 67½" Radius 108" in Arc	22 No. 1 Wedge 29 Square 75" Radius 113" in Arc	21 No. 1 Wedge 32 Square 83" Radius 119" in Arc	21 No. 1 Wedge 34 Square 91" Radius 125" in Arc
25-in.	28 No. 1 Wedge 25 Square 58½" Radius 114" in Arc	26 No. 1 Wedge 28 Square 64½" Radius 119" in Arc	26 No. 1 Wedge 30 Square 70½" Radius 125" in Arc	24 No. 1 Wedge 34 Square 77½" Radius 130" in Arc

UNION MINING COMPANY

NUMBER OF FIRE BRICK REQUIRED FOR ONE COURSE OF AN ARCH 9 INCHES THICK OF VARIOUS SPANS AND SPRINGS.

Spring	SPAN		
	10 Ft.	10 Ft., 6 In.	11 Ft.
12-in.	11 No. 1 Wedge 38 Square 156″ Radius 124″ in Arc	11 No. 1 Wedge 41 Square 171″ Radius 180″ in Arc	10 No. 1 Wedge 44 Square 188″ Radius 136″ in Arc
15-in.	14 No. 1 Wedge 40 Square 127½″ Radius 127″ in Arc	14 No. 1 Wedge 42 Square 140″ Radius 132″ in Arc	13 No. 1 Wedge 45 Square 153″ Radius 138″ in Arc
20 in.	19 No. 1 Wedge 38 Square 100″ Radius 131″ in Arc	18 No. 1 Wedge 41 Square 109″ Radius 136″ in Arc	18 No. 1 Wedge 43 Square 119″ Radius 142″ in Arc
25-in	23 No. 1 Wedge 37 Square 85″ Radius 136″ in Arc	23 No. 1 Wedge 39 Square 91″ Radius 141″ in Arc	22 No. 1 Wedge 42 Square 100″ Radius 146″ in Arc
30-in.	26 No. 1 Wedge 37 Square 75″ Radius 141″ in Arc	26 No. 1 Wedge 39 Square 80½″ Radius 146″ in Arc	25 No. 1 Wedge 40 Square 87½″ Radius 151″ in Arc

Circumferences and Areas of Circles from 1-64 to 100

Diam.	Circum.	Area	Diam.	Circum.	Area
1/64	.04909	.000192	4	12.5664	12.5664
1/32	.09818	.000767	4 1/8	12.9591	13.3641
1/16	.19635	.003068	4 1/4	13.3518	14.1863
1/8	.3927	.012272	4 3/8	13.7445	15.033
3/16	.589	.027612	4 1/2	14.1372	15.9043
1/4	.7854	.049087	4 5/8	14.5299	16.8002
5/16	.98175	.076699	4 3/4	14.9226	17.7206
3/8	1.1781	.110447	4 7/8	15.3153	18.6555
7/16	1.37445	.15033			
1/2	1.5708	.19635	5	15.708	19.635
9/16	1.76715	.248505	5 1/8	16.1007	20.629
5/8	1.9635	.306796	5 1/4	16.4934	21.6476
11/16	2.15985	.371224	5 3/8	16.8861	22.6907
3/4	2.3562	.441787	5 1/2	17.2788	23.7583
13/16	2.55255	.518487	5 5/8	17.6715	24.8505
7/8	2.7489	.601322	5 3/4	18.0642	25.9673
15/16	2.94525	.690292	5 7/8	18.4569	27.1086
1	3.1416	.7854	6	18.8496	28.2744
1 1/8	3.5343	.99402	6 1/8	19.2423	29.4648
1 1/4	3.927	1.2272	6 1/4	19.635	30.6797
1 3/8	4.3197	1.4849	6 3/8	20.0277	31.9191
1 1/2	4.7124	1.7671	6 1/2	20.4204	33.1831
1 5/8	5.1051	2.0739	6 5/8	20.8131	34.4717
1 3/4	5.4978	2.4053	6 3/4	21.2058	35.7848
1 7/8	5.8905	2.7612	6 7/8	21.5985	37.1224
2	6.2832	3.1416	7	21.9912	38.4846
2 1/8	6.6759	3.5466	7 1/8	22.3839	39.8713
2 1/4	7.0686	3.9761	7 1/4	22.7766	41.2826
2 3/8	7.4613	4.4301	7 3/8	23.1693	42.7184
2 1/2	7.854	4.9087	7 1/2	23.562	44.1787
2 5/8	8.2467	5.4119	7 5/8	23.9547	45.6636
2 3/4	8.6394	5.9396	7 3/4	24.3474	47.1731
2 7/8	9.0321	6.4918	7 7/8	24.7401	48.7071
3	9.4248	7.0686	8	25.1328	50.2656
3 1/8	9.8175	7.6699	8 1/8	25.5255	51.8487
3 1/4	10.2102	8 2958	8 1/4	25.9182	53.4563
3 3/8	10.6029	8.9462	8 3/8	26.3109	55.0884
3 1/2	10.9956	9.6211	8 1/2	26.7036	56.7451
3 5/8	11.3883	10.3206	8 5/8	27.0963	58.4264
3 3/4	11.781	11.0447	8 3/4	27.489	60.1322
3 7/8	12.1737	11.7933	8 7/8	27.8817	61.8625

Circumferences and Areas of Circles
Continued

Diam.	Circum.	Area	Diam.	Circum.	Area
9	28.2744	63.6174	15	47.124	176.715
9⅛	28.6671	65.3968	15⅛	47.5167	179.673
9¼	29.0598	67.2008	15¼	47.9094	182.655
9⅜	29.4525	69.0293	15⅜	48.3021	185.661
9½	29.8452	70.8823	15½	48.6948	188.692
9⅝	30.2379	72.7599	15⅝	49.0875	191.748
9¾	30.6306	74.6621	15¾	49.4802	194.828
9⅞	31.0233	76.5888	15⅞	49.8729	197.933
10	31.416	78.54	16	50.2656	201.062
10⅛	31.8087	80.5158	16⅛	50.6583	204.216
10¼	32.2014	82.5161	16¼	51.051	207.395
10⅜	32.5941	84.5409	16⅜	51.4437	210.598
10½	32.9868	86.5903	16½	51.8364	213.825
10⅝	33.3795	88.6643	16⅝	52.2291	217.077
10¾	33.7722	90.7628	16¾	52 6218	220.354
10⅞	34.1649	92.8858	16⅞	53.0145	223.655
11	34.5576	95.0334	17	53.4072	226.981
11⅛	34.9503	97.2055	17⅛	53.7999	230.331
11¼	35.343	99.4022	17¼	54.1926	233.906
11⅜	35.7357	101.6234	17⅜	54.5853	237.105
11½	36.1284	103.8691	17½	54.978	240.529
11⅝	36.5211	106.1394	17⅝	55.3707	243.977
11¾	36.9138	108.4343	17¾	55 7634	247.45
11⅞	37.3065	110.7537	17⅞	56.1561	250.948
12	37.6992	113.098	18	56.5488	254.47
12⅛	38.0919	115.466	18⅛	56.9415	258.016
12¼	38.4846	117.859	18¼	57.3342	261.587
12⅜	38.8773	120.277	18⅜	57.7269	265.183
12½	39.27	122.719	18½	58.1196	268.803
12⅝	39.6627	125.185	18⅝	58.5123	272.448
12¾	40.0554	127.677	18¾	58.905	276.117
12⅞	40.4481	130.192	18⅞	59.2977	279.811
13	40.8408	132.733	19	59.6904	283.529
13⅛	41.2335	135.297	19⅛	60.0831	287.272
13¼	41.6262	137.887	19¼	60.4758	291.04
13⅜	42.0189	140.501	19⅜	60.8685	294.832
13½	42.4116	143.139	19½	61.2612	298.648
13⅝	42.8043	145.802	19⅝	61.6539	302.489
13¾	43.197	148.49	19¾	62.0466	306.355
13⅞	43.5897	151.202	19⅞	62.4393	310.245
14	43.9824	153.938	20	62.832	314.16
14⅛	44.3751	156.7	20⅛	63.2247	318.099
14¼	44.7678	159.485	20¼	63.6174	322.063
14⅜	45.1605	162.296	20⅜	64.0101	326.051
14½	45.5532	165.13	20½	64.4028	330.064
14⅝	45.9459	167.99	20⅝	64.7955	334.102
14¾	46.3386	170.874	20¾	65.1882	338.164
14⅞	46.7313	173.782	20⅞	65 5809	342 25

Circumferences and Areas of Circles
Continued

Diam.	Circum.	Area	Diam.	Circum.	Area
21	65.9736	346.361	27	84.8232	572.557
21⅛	66.3663	350.497	27⅛	85.2159	577.87
21¼	66.759	354.657	27¼	85.6086	583.209
21⅜	67.1517	358.842	27⅜	86.0013	588.571
21½	67.5444	363.051	27½	86.394	593.959
21⅝	67.9379	367.285	27⅝	86.7867	599.371
21¾	68.3298	371.543	27¾	87.1794	604.807
21⅞	68.7225	375.826	27⅞	87.5729	610.268
22	69.1152	380.134	28	87.9648	615.754
22⅛	69.5079	384.466	28⅛	88.3575	621.264
22¼	69.9006	388.822	28¼	88.7502	626.798
22⅜	70.2933	393.203	28⅜	89.1429	632.357
22½	70.686	397.609	28½	89.5356	637.941
22⅝	71.0787	402.038	28⅝	89.9283	643.549
22¾	71.4714	406.494	28¾	90.321	649.182
22⅞	71.8641	410.973	28⅞	90.7137	654.84
23	72.2568	415.477	29	91.1064	660.521
23⅛	72.6495	420.004	29⅛	91.4991	666.228
23¼	73.0422	424.558	29¼	91.8918	671.959
23⅜	73.4349	429.135	29⅜	92.2845	677.714
23½	73.8276	433.737	29½	92.6772	683.494
23⅝	74.2203	438.364	29⅝	93.0699	689.299
23¾	74.613	443.015	29¾	93.4626	695.128
23⅞	75.0057	447.69	29⅞	93.8553	700.982
24	75.3984	452.39	30	94.248	706.86
24⅛	75.7911	457.115	30⅛	94.6407	712.763
24¼	76.1838	461.864	30¼	95.0334	718.69
24⅜	76.5765	466.638	30⅜	95.4261	724.642
24½	76.9692	471.436	30½	95.8188	730.618
24⅝	77.3619	476.259	30⅝	96.2115	736.619
24¾	77.7546	481.107	30¾	96.6042	742.645
24⅞	78.1473	485.979	30⅞	96.9969	748.695
25	78.54	490.875	31	97.3896	754.769
25⅛	78.9327	495.796	31⅛	97.7823	760.869
25¼	79.9254	500.742	31¼	98.175	766.992
25⅜	79.7181	505.712	31⅜	98.5677	773.14
25½	80.1108	510.706	31½	98.9604	779.313
25⅝	80.5035	515.726	31⅝	99.3531	785.51
25¾	80.8962	520.769	31¾	99.7458	791.732
25⅞	81.4889	525.838	31⅞	100.1385	797.979
26	81.6816	530.93	32	100.5312	804.25
26⅛	82.0743	536.048	32⅛	100.9239	810.545
26¼	82.476	541.19	32¼	101.3166	816.865
26⅜	82.8597	546.356	32⅜	101.7093	823.21
26½	83.2524	551.547	32½	102.102	829.579
26⅝	83.6451	556.763	32⅝	102.4947	835.972
26¾	84.0378	562.003	32¾	102.8874	842.391
26⅞	84.4305	567.267	32⅞	103.2801	848.833

CIRCUMFERENCES AND AREAS OF CIRCLES
CONTINUED

Diam.	Circum.	Area	Diam.	Circum.	Area
33	103.673	855.301	39	122.522	1194.593
33⅛	104.065	861.792	39⅛	122.915	1202.263
33¼	104.458	868.309	39¼	123.308	1209.958
33⅜	104.851	874.85	39⅜	123.7	1217.677
33½	105.344	881.415	39½	124.093	1225.42
33⅝	105.636	888.005	39⅝	124.486	1233.188
33¾	106.029	894.62	39¾	124.879	1240.981
33⅞	106.422	901.259	39⅞	125.271	1248.798
34	106.814	907.922	40	125.664	1256.64
34⅛	107.207	914.611	40⅛	126.057	1264.51
34¼	107.6	921.323	40¼	126.449	1272.4
34⅜	107.992	928.061	40⅜	126.842	1280.31
34½	108.385	934.822	40½	127.235	1288.25
34⅝	108.778	941.609	40⅝	127.627	1296.22
34¾	109.171	948.42	40¾	128.02	1304.21
34⅞	109.563	955.255	40⅞	128.413	1312.22
35	109.956	962.115	41	128.806	1320.26
35⅛	110.349	969.	41⅛	129.198	1328.32
35¼	110.741	975.909	41¼	129.591	1336.41
35⅜	111.134	982.842	41⅜	129.984	1344.52
35½	111.527	989.8	41½	130.376	1352.66
35⅝	111.919	996.783	41⅝	130.769	1360.82
35¾	112.312	1003.79	41¾	131.162	1369.
35⅞	112.705	1010.822	41⅞	131.554	1377.21
36	113.098	1017.878	42	131.947	1385.45
36⅛	113.49	1024.96	42⅛	132.34	1393.7
36¼	113.883	1032.065	42¼	132.733	1401.99
36⅜	114.276	1039.195	42⅜	133.125	1410.3
36½	114.668	1046.349	42½	133.518	1418.63
36⅝	115.061	1053.528	42⅝	133.911	1426.99
36¾	115.454	1060.732	42¾	134.303	1435.37
36⅞	115.846	1067.96	42⅞	134.696	1443.77
37	116.239	1075.213	43	135.089	1452.2
37⅛	116.632	1082.49	43⅛	135.481	1460.66
37¼	117.025	1089.792	43¼	135.874	1469.14
37⅜	117.417	1097.118	43⅜	136.267	1477.64
37½	117.81	1104.469	43½	136.66	1486.17
37⅝	118.203	1111.844	43⅝	137.052	1494.73
37¾	118.595	1119.244	43¾	137.445	1503.3
37⅞	118.988	1126.669	43⅞	137.838	1511.91
38	119.381	1134.118	44	138.23	1520.53
38⅛	119.773	1141.591	44⅛	138.623	1529.19
38¼	120.166	1149.089	44¼	139.016	1537.86
38⅜	120.559	1156.612	44⅜	139.408	1546.56
38½	120.952	1164.159	44½	139.801	1555.29
38⅝	121.344	1171.731	44⅝	140.194	1564.04
38¾	121.737	1179.327	44¾	140.587	1572.81
38⅞	122.13	1186.948	44⅞	140.979	1581.61

UNION MINING COMPANY

CIRCUMFERENCES AND AREAS OF CIRCLES CONTINUED

Diam.	Circum.	Area	Diam.	Circum.	Area
45	141.372	1590.43	51	160.22	2042.82
45⅛	141.765	1599.28	52	163.36	2123.71
45¼	142.157	1608.16	53	166.50	2206.18
45⅜	142.55	1617.05	54	169.65	2290.21
45½	142.943	1625.97	55	172.79	2375.82
45⅝	143.335	1634.92	56	175.93	2463.01
45¾	143.728	1643.89	57	179.07	2551.75
45⅞	144.121	1652.89	58	182.21	2642.08
			59	185.35	2733.97
			60	188.50	2827.43
46	144.514	1661.91	61	191.64	2922.46
46⅛	144.906	1670.95	62	194.78	3019.07
46¼	145.299	1680.02	63	197.92	3117.24
46⅜	145.692	1689.11	64	201.06	3216.99
46½	146.084	1698.23	65	204.20	3318.30
46⅝	146.477	1707.37	66	207.35	3421.18
46¾	146.87	1716.54	67	210.49	3525.65
46⅞	147.262	1725.73	68	213.63	3631.68
			69	216.77	3739.28
			70	219.91	3848.45
47	147.655	1734 95	71	223.05	3959.19
47⅛	148.048	1744.19	72	226.19	4071.50
47¼	148.441	1753.45	73	229.34	4185.38
47⅜	148.833	1762.74	74	232.48	4300.84
47½	149.226	1772.06	75	235.62	4417.86
47⅝	149.619	1781.4	76	238.76	4536.45
47¾	150.011	1790.76	77	241.90	4656.62
47⅞	150.404	1800.15	78	245.04	4778.36
			79	248.19	4901.66
			80	251.33	5026.54
48	150.797	1809.56	81	254.47	5153.00
48⅛	151.189	1819.	82	257.61	5281.01
48¼	151.582	1828.46	83	260.75	5410.59
48⅜	151.975	1837.95	84	263.89	5541.77
48½	152.368	1847.46	85	267.04	5674.50
48⅝	152.76	1856.99	86	270.18	5808.80
48¾	153.153	1866.55	87	273.32	5944.67
48⅞	153.546	1876.14	88	276.46	6082.11
			89	279.60	6221.13
			90	282.74	6361.72
49	153.938	1885.75	91	285.88	6503.87
49⅛	154.331	1895.38	92	289.03	6647.61
49¼	154.724	1905.04	93	292.17	6792.90
49⅜	155.116	1914.72	94	295.31	6939.78
49½	155.509	1924.43	95	298.45	7088.21
49⅝	155.902	1934.16	96	301.59	7238.23
49¾	156.295	1943.91	97	304.73	7389.81
49⅞	156.687	1953.69	98	307.88	7542.96
			99	311.02	7697.68
50	157.08	1963.5	100	314.16	7853.97

CRUSHING LOADS FOR STONE, BRICK, MASONRY.

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	Compression
Granite, Aberdeen.	10.910
Granite, Dublin	10,440
Whinstone, Scotch	8,283
Red, Sandstone, Runeorn	2,176
Limestone compact	7,705
Limestone magnesian	3,046
Brickwork, in cement, fresh	·519
Brick, hard	2,000 4,368
Brick, common stock	4,800 800
Portland cement, 3 mos.	3,808
Portland cement, 1, to 1 of sand Portland cement, 3 mos. old	2,486
Portland cement, 1, to 5 of sand Portland cement, 3 mos. old	963
Portland cement, 9 mos. old	5,971
Portland cement, 1, to 1 of sand Portland cement, 9 mos. old	4,570
Portland cement, 1, to 5 of sand Portland cement, 9 mos. old	1,630
Portland cement, concrete, 12 mos.—	
1 cement, 1 sand and gravel	2,652
1 cement, 3 sand and gravel	1,797
1 cement, 6 sand and gravel	1,409
Mortar, lime and river sand	434
Mortar, lime and river sand beaten	595
Brick work, average, ordinary	390
Brick work, average, in cement	544
Brick work, superior, in cement	933
Freestone, Bellville	3,522
Freestone, Connecticut	3,319
Freestone, Dorchester	3,069
Gneiss	19,600
Granite, Quincy	15,300
Marble, Italian	12,624
Marble, Tennessee, gray or pink	17,000
Marble, Georgia	14,000
Marble Stockbridge	10,382
Marble Symington, large	11,156
Roman Cement	342
Sandstone, Acquia Creek	5,340
Sandstone Seneca	10,762

WEIGHTHS AND SPECIFIC GRAVITY OF VARIOUS MATERIALS.

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	Specific Gravity	Weight per cu. ft.
Water at 62° Fahr.	1.000	62.321
METALS		
Platinum	21.522	1342.000
Gold	19.425	1205.000
Mercury	13.596	848.750
Lead	11.418	712.000
Silver	10.505	655.000
Bismuth	9.900	616.978
Copper, sheet	8.805	549.000
" cast	8.600	537.000
Gun-metal	8.560	533.468
Nickel, hammered	8.670	540.223
" cast	8.280	516.018
Bearing metal, 79 copper, 21 tin	8.730	544.062
Brass, wire	8.540	533.000
" cast, 75 copper, 25 zinc	8.450	526.612
" " 66 " 34 "	8.300	517.264
" " 60 " 40 "	8.200	511.032
Bronze	8.400	524.000
Steel	7.852	490.000
Iron, wrought, average	7.698	480.000
" cast "	7.110	444.000
Zinc, sheet	7.200	449.000
" cast	6.860	424.000
Tin	7.409	462.000
Antimony	6.710	418.174
Aluminum, cast	2.560	159.542
MINERALS, MASONRY, ETC.		
Manganese	8.00	498.568
Basalt	3.00	187.000
Glass, flint	3.00	187.000
" plate	2.70	169.000
Marble	2.84 2.52	176.991 157.049
Granite	3.06 2.36	190.702 147.077
Soapstone	2.73	140.000
Flint	2.63	164.200
Feldspar	2.60	162.300
Limestone	2.8 2.7	175.000 169.000
Slate	2.90 2.80	181.000 175.000
Quartz	1.26 2.65	78.524 165.000
Shale	2.60	162.000

WEIGHTS, ETC.—Continued.

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	Specific Gravity.	Weight per cu. ft.
Sandstone, average	2.30	144.000
Gypsum, plaster of paris	2.30	144.000
Masonry	2.30 1.85	144.000 116.000
Graphite	2.20	137.106
Brick	2.167 2.000	135.000 125.000
Sulphur	2.00	125.000
Clay	1.92	120.000
Sand, damp	1.9	118 000
" dry	1.42	88.600
Marl	1.90 1.60	119.000 100 000
Coal, anthracite	1.602	100.000
" bituminous	1.44 1.24	89.900 77.400
Coke, dry, loose, average	0.449	28.000
Cement, American, Rosendale	....	60.000
LIQUIDS.		
Acid, sulphuric	1.840	114.670
" nitric	1.220	76.031
" acetic	1.080	67.306
Milk	1.030	64.100
Sea water	1.026	64.050
Linseed oil	0.940	58.680
Sperm oil	0.923	57.620
Olive oil	0 915	57.120
Alcohol, proof spirit	0.920	57.335
" pure	0.791	49.380
Petroleum	0.878	54.810
Turpentine, oil	0.870	54.310
Naptha	0.848	52.940
Ether	0.716	44.700
TIMBER.		
Ash	0.753	47.0
Bamboo	0.400	25.0
Beech	0.690	43.0
Birch	0.711	44.4
Blue Gum	0.834	52 5
Boxwood	0.960	60 0
Cedar, American	0.559	35.0
Cherry, dry	0.672	42.0
Chestnut	0.535	33.4
Cork	0.250	15.6
Ebony, West India	1.193	74.5
Elm	0.544	34.0
Greenheart	1.001	62.5
Hawthorn	0.910	57.0

WEIGHTS, ETC.—Continued.

From "Manuel for Engineers", Copyrighted by Charles E. Ferris. B. S.

	Specific Gravity	Weight per cu. ft.
Hazel	0.860	54.0
Hemlock, dry	0.400	25.0
Holly	0.760	47.0
Hickory	0.850	53.0
Hornbeam	0.760	47.0
Laburnum	0.920	57.0
Lancewood	1.010 0.675	63.0 42.0
Lignum Vitæ	1.330 0.650	83.0 41.0
Locust	0.710	44.0
Mahogany, Honduras	0.560	35.0
" Spanish	0.850	53.0
Maple	0.790	49.0
Oak, live, dry	0.950	59.3
" white, dry	0.830	51.8
Pine, white, dry	0.400	25.0
" yellow, dry	0.550	34.3
" Southern, dry	0.720	45.0
Sycamore	0.590	37.0
Teak, Indian	0.880 0.660	55.0 41.0
Water Gum	1.001	62.5
Walnut	0.610	38.0
Willow	0.400	25.0
Yew	0.800	50.0
MISCELLANEOUS.		
Ivory	1.82	114.000
India rubber	1.93	58.000
Lard	0.95	59.300
Gutta Percha	0 98	61.100
Beeswax	0.97	60.500
Turf, dry, loose	0.401	25.000
Pitch	1.15	71.700
Fat	0.93	58.000
Tallow	0.936	58.396

GASES.

Weight per cubic foot at 32° Fahr. and under pressure of one atmosphere.

Air	0.080728
Carbonic Acid	0.12344
Hydrogen	0.005592
Oxygen	0.089256
Nitrogen	0.078596
Steam (ideal) Rankine	0.05022
Vapor of Ether, Rankine (ideal)	0.2093
" " Bi-sulphide of carbon, Rankine	0.2137
Olefiant gas (marsh gas)	0.0795

TEMPERATURES

Below is given the fusion points of iron, steel and other metals, and some refractory oxides, according to the latest investigations:

(The figures given below, with exception of brass, cast iron, steel, wrought iron, are taken from a 1918 publication of the Bureau of Standards.)

(The figures for Kaolin, Alumina, and Magnesia are the work of Sosman, of the Geographical Laboratory, Washington.)

	Centigrade Degrees	Fahrenheit Degrees
Tin	231.9	449.4
Lead	327.4	621.3
Zinc	419.4	782.9
Antimony	630.0	986.0
Aluminum	658.7	1217.7
Silver	960.5	1760.9
Brass	1021	1870
Gold	1063.0	1945.5
Copper	1083.0	1981.4
Cast Iron, white	1135	2075
Cast Iron, gray	1222	2230
Steel	1300	2372
Iron, wrought	1500	2732
Nickel	1452	2646
Platinum	1755	3191
Silica	1750	3182
Kaolin	1755	3191
Alumina	2050	3722
Magnesia	2800	5072

TEMPERATURES—CONTINUED

	Centigrade Degrees	Fahrenheit Degrees
Glass Furnace, between the pots.	1375	2507
In the pots, refining	1310	2390
In the pots, working............	1045	1913
Tanks melted for casting.........	1310	2390
Annealing Glassware............	444 to 555	800 to 1000
Siemens Crucible Steel Furnace varies from	1460 to 1590	2660 to 2894
BESSEMER PROCESS		
Running the slag	1580	2876
Running steel into ladle...........	1640	2984
Running steel into mold.	1580	2876
Soaking pit furnace, ingot in....	1200	2192
Ingot under hammer...............	1080	1976
OPEN HEARTH PROCESS		
Gas from producers	720	1328
Gas entering generator	400	752
Gas leaving generator	1200	2192
Air leaving generator..............	1000	1832
Fumes passing to shaft............	300	572
End of fusion of charge...........	1420	2588
Refining the steel.......	1500	2732
Running into ladle, first.........	1580	2876
Running into ladle, last	1490	2714
BLAST FURNACE—GREY BESSEMER		
Front of tuyere.........................	1930	3506
At tapping.............................	1570	2858

EFFECT OF HEAT ON VARIOUS SUBSTANCES.

From "Manuel for Engineers", Copyrighted by Charles E. Ferris, B. S.

	Cent.	Fahr.
Tungsten melts	3000	5441
Laudatum melts	2900	5252
Magnesia melts	2800	5072
Lime melts	2570	4658
Iron boils	2450	4442
Copper boils	2300	4172
Tin boils	2270	4118
Silver boils	1950	3542
Platinum melts	1755	3191
Palladium melts	1549	2822
Iron melts	1530	2786
Lead boils	1525	2777
Copper melts	1083	1981
Copper melts (in air)	1063	1945
Gold melts	1063	1945
Silver melts	961	1762
Aluminum melts	658	1218
Antimony melts	630	1166
Sulphur boils	444	832
Zinc melts	419	787
Lead melts	327	621
Tin melts	232	450
Water boils	100	212
Ice melts	0	32
Mercury melts	—39	—38

	Cent.	Fahr.
Oxygen boils	—183	—287
Hydrogen boils	—253	—423
Hydrogen melts	—259	—434
Lowest temp. reached	—271	—457
Absolute zero	—273	—460
Bismuth melts	271	520
Cadmium melts	321	610
Manganese melts	1225	2237
Nickel	1450	2642
Cobalt	1490	2714
Rhodium	1920	3488
Chromium	1510	2750

Important Industrial Temperatures (Mean)

Steel and Iron

	Cent.	Fahr.
Blast furnace, hot part	1700	3092
Open hearth furnace	1600	2912
Bessemer converter	1600	2912
Melting range steel	1437	2618
Melting range cast iron	1175	2147
Rolling steel (finishing)	875	1607
Annealing and hardening carbon steel	837	1538
Tempering (usual)	250	482

Other Metals

	Cent.	Fahr.
Melting zinc bronze	1005	1841
Pouring zinc bronze	1210	2210
Melting brass	917	1682
Pouring brass	1062	1943

Clay Products

	Cent.	Fahr.
Firing common brick	1045	1913
Firing fire clay brick	1225	2237
Firing vitrified brick	1100	2012
Firing stoneware pottery (dense)	1120	2048
White ware, table ware, biscuit fire	1215	2219
White ware, table ware, glost fire	1115	2057
European hard porcelain, biscuit fire	900	1652
European hard porcelain, glost fire	1330	2426
Overglaze and gold decorations	695	1283
Melting point fire clay brick	1642	2987

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THE METALLURGISTS AND CHEMISTS' HANDBOOK
Compiled by Donald M. Liddell, C. E.

COLOR SCALES[1]

White and Taylor		Pouillet		Howe	
Name of color	Deg. C.	Name of color	Deg. C.	Name of color	Deg. C.
....	....	....	....	Lowest visible red in dark......	470
....	....	Incipient redness................	525	Lowest visible red in daylight.	475
Dark red..........	566	Dark red.........	700	Dull red..........	550–625
Dark cherry red.	635	Incipientcherry red...............	800		
Cherry, full red.	746	Cherry red.......	900	Full cherry..........	700
Light, cherry bright cherry, light red..........	843	Light cherry red..........	1000	Light red............	850
Orange..............	899	Dark orange....	1100	....	....
Light orange......	941	Light orange....	1200	....	....
Yellow..............	996	....	....	Full yellow........	950–1000
White..............	1205	White..............	1300	White..................	1150
....	....	Brilliant white.	1400	....	....
....	....	Dazzling white	1500–1600	....	.....

[1] HOFMAN, "General Metallurgy," p. 138.

TABLE SHOWING
SOFTENING POINTS OF SEGAR-ORTON PYROMETRIC CONES

When cones were first made, the melting point of platinum was considered higher than it is now believed to be. Since this is a standard point in all high-temperature scales, the recorded melting points of the higher cones were too high. Cones 20 to 26 were considered as melting at 20° C. intervals. The Bureau of Standards, United States Government, has found that cones 20 to 25 all melt at the same temperature, and that cones 21 to 25 are worthless. The difference between cones 20 and 26 is 70° C. instead of 120° C. Thus, while the cones have always melted at the same temperatures, the interpretation has led to confusion. Even today, clay fusing at cone 32 may be reported at 3218° F. or 3128° F. according to the scale used.

The Bureau of Standards and the manufacturers agree on the melting points of all cones up to No. 20 inclusive. We give below the softening points according to the makers as well as those determined by the Bureau of Standards.

The figures given apply when cones are melted in about three hours—in commercial kilns they melt about 100° F. lower, because of the greater influence of time.

SOFTENING POINTS OF SEGER-ORTON CONES

Cone Numbers	According to Maker		According to Bureau of Standards	
022	1094° F.	590° C.	1094° F.	590° C.
021	1148	620	1148	620
020	1202	650	1202	650
019	1256	680	1256	680
018	1310	710	1310	710
017	1364	740	1364	740
016	1418	770	1418	770
015	1472	800	1472	800
014	1526	830	1526	830
013	1580	860	1580	860
012	1634	890	1634	890
011	1688	920	1688	920
010	1742	950	1742	950
09	1778	970	1778	970
08	1814	990	1814	990
07	1850	1010	1850	1010
06	1886	1030	1886	1030
05	1922	1050	1922	1050
04	1958	1070	1958	1070
03	1994	1090	1994	1090
02	2030	1110	2030	1110
01	2066	1130	2066	1130

SOFTENING POINTS OF SEGER-ORTON CONES
Continued

Cone Numbers	According to Maker		According to Bureau of Standards	
1	2102° F.	1150° C.	2102° F.	1150° C.
2	2138	1170	2138	1170
3	2174	1190	2174	1190
4	2210	1210	2210	1210
5	2246	1230	2246	1230
6	2282	1250	2282	1250
7	2318	1270	2318	1270
8	2354	1290	2354	1290
9	2390	1310	2390	1310
10	2426	1330	2426	1330
11	2462	1350	2462	1350
12	2498	1370	2498	1370
13	2534	1390	2534	1390
14	2570	1410	2570	1410
15	2606	1430	2606	1430
16	2642	1450	2642	1450
17	2678	1470	2678	1470
18	2714	1490	2714	1490
19	2750	1510	2750	1510
20	2786	1530	2786	1530
21	2822	1550	....	....
22	2858	1570	....	....
23	2894	1590	....	....
24	2930	1610	....	....
25	2966	1630	....	....
26	3002	1650	2912	1600
27	3038	1670	2948	1620
28	3074	1690	2975	1635
29	3110	1710	3002	1650
30	3146	1730	3038	1670
31	3182	1750	3065	1685
32	3218	1770	3101	1705
33	3254	1790	3128	1720
34	3290	1810	3164	1740
35	3326	1830	3200	1760
36	3362	1850	3236	1780
37	3398	1870	3272	1800
38	3434	1890	3308	1820
39	3470	1910	3344	1840
40	3506	1930	3380	1860

STANDARD DEFINITIONS FOR CLAY REFRACTORIES

AS ADOPTED BY

AMERICAN SOCIETY FOR TESTING MATERIALS

AND REPRINTED WITH ITS PERMISSION

Serial Designation: C 27—20.

These definitions are issued under the fixed designation C 27; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED, 1920.

1. The following definitions relating to the resistance to heat and the constancy of volume of clay refractories are recommended for the purpose of classification.

Method of Determining Softening Point.

2. The softening point referred to in the following definitions shall be determined in accordance with the Standard Method of Test for Softening Point of Fire Clay Brick (Serial Designation: C 24) of the American Society for Testing Materials.

Test for Linear Contraction or Expansion.

3. The test for linear contraction or expansion referred to in the following definitions shall be conducted in accordance with the Standard Method of Test for Porosity and Permanent Volume Changes in Refractory Materials (Serial Designation: C 20) of the American Society for Testing Materials.

I. HIGH HEAT DUTY BRICK.

(*A*) *Clay Fire Brick.*

(Silica content less than 70 per cent.)

Softening Point.

4. The softening point of clay fire brick for high heat duty shall not be lower than that of standard cone No. 31 (about 1685° C., or 3065° F.).

Linear Contraction or Expansion.

5. When duplicate samples of clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of 1400° C. (2552° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent. of the original length nor an expansion of more than 1 per cent.

Option.

6. When a brick of this type softens at a temperature not below the softening point of standard cone No. 29 (about 1650° C., or 3002° F.), it may be tested according to classification (*B*) for silicious clay fire brick without losing in standing if it passes the tests.

(*B*) *Silicious Clay Fire Brick*

(Silica contents 70 per cent. or over.)

Softening Point.

7. The softening point of silicious clay fire brick for high heat duty shall not be lower than that of standard cone No. 28 (about 1635° C., or 2975° F.).

Load Test.

8. All silicious clay fire brick for high heat duty shall be subjected to a load test in accordance with the requirements of the Standard Test for Refractory Materials under Load at High Temperatures (Serial Designation : C 16) of the American Society for Testing Materials. The pressure to be applied upon the brick (placed on end) shall be 25 lb. per sq. in. and the maximum furnace temperature 1350° C. (2462° F.). The brick shall not show a contraction of more than 4 per cent. of the original length, nor an expansion of more than 1 per cent.

Linear Contraction or Expansion.

9. When duplicate samples of silicious clay fire brick for high heat duty are heated uniformly in a suitable furnace to a temperature of 1400° C. (2552° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent. of the original length nor an expansion of more than 1 per cent.

II. INTERMEDIATE HEAT DUTY BRICK.

Softening Point.

10. The softening point of brick for intermediate heat duty shall not be lower than that of standard cone No. 28 (about 1635° C., or 2975° F.).

Linear Contraction or Expansion.

11. When duplicate samples of brick for intermediate heat duty are heated uniformly in a suitable furnace to a temperature of 1350° C. (2462° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent. of the original length nor an expansion of more than 1 per cent.

III. MODERATE HEAT DUTY BRICK.

Softening Point.

12. The softening point of brick for moderate heat duty shall not be lower than that of standard cone No. 26 (about 1600° C., or 2912° F.).

Linear Contraction or Expansion.

13. When duplicate samples of brick for moderate heat duty are heated uniformly in a suitable furnace to a temperature of 1290° C. (2354° F.), maintained at this temperature for 5 hours, and cooled, they shall not show a contraction of more than 1.5 per cent of the original length nor an expansion of more than 1 per cent.

IV. LOW HEAT DUTY BRICK.

Softening Point.

14. The softening point of brick for low heat duty shall not be lower than that of standard cone No. 19 (about 1510° C., or 2750° F.).

STANDARD METHOD OF TEST FOR

REFRACTORY MATERIALS UNDER LOAD AT HIGH TEMPERATURES.

AS ADOPTED BY

AMERICAN SOCIETY FOR TESTING MATERIALS

AND REPRINTED WITH ITS PERMISSION

Serial Designation: C 16—20.

This method is issued under the fixed designation C 16; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1917; ADOPTED IN AMENDED FORM, 1920.

Object.

1. The object of this test is to determine the resistance of the specimen to deformation at a specified temperature for a specified time, when subjected to a compressive load of 25 lb. per sq. in. (1.765 kg. per sq. cm.).

Apparatus.

2. The apparatus consists essentially of a furnace and loading device. It shall be constructed in accordance with Figs. 1 and 2.

(*a*) The furnace shall be cylindrical in form, 18 in. (457 mm.) in internal diameter, as shown in Fig. 1 (Plate IV).

(*b*) The heating shall be done with gaseous or oil fuel and compressed air, using not less than two burners located tangentially and so arranged that no flame can impinge upon the test specimen. The burners shall be such as will insure a uniform temperature in all parts of the furnace and be under complete control.

(*c*) The method of loading shown in Fig. 1 shall be used, and the details shall be such as will insure accuracy in the applied load and freedom from eccentric loading, both in the original application and during the testing. It is advantageous to make the cross-beams as light as possible, so that the greater portion of the load may be concentrated in the weights.

(*d*) The temperature may be measured either with a calibrated platinum-rhodium thermo-couple, encased in a double protecting tube with the junction not more than 1 in. (25 mm.) from the side or edge of the specimen and approximately opposite the center; or with some form of optical pyrometer that has been calibrated against a thermo-couple in the furnace. If the thermo-couple is used, the cold-end temperature should be kept constant in melted ice. A recording form of indicator is recommended where possible.

Test Specimen.

8. The test specimen shall consist, whenever possible, of a standard 9-in. brick placed vertically on end. In the case of blocks or shapes, sections approximately 9 by 4½ by 2½ in. (228 by 114 by 64 mm.) shall be cut, utilizing as far as possible existing plane

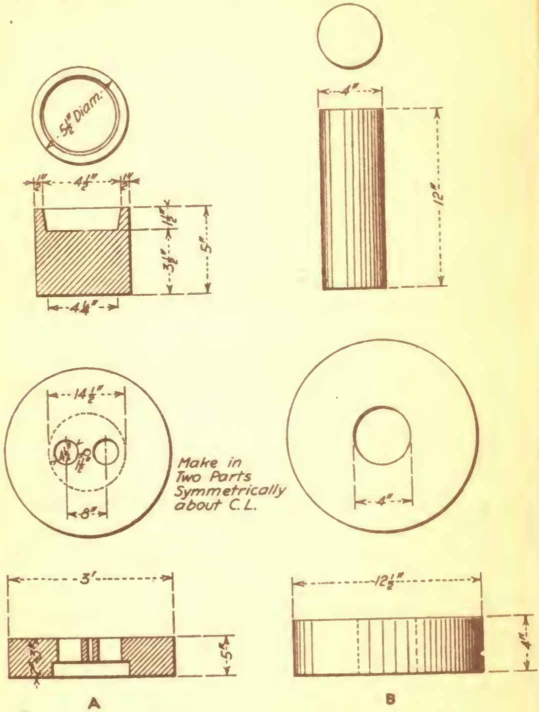


Fig. 2.—Special Shapes Required for Furnace.
(By courtesy of *Metallurgical and Chemical Engineering.*)

surfaces. The ends of the specimen shall be either ground so that they are parallel and perpendicular to the vertical axis, or if this is impossible, shall be bedded in a neutral cement, so that the specimen is perpendicular to the base of the furnace.

TABLE I.—TEMPERATURE TO BE ATTAINED AT TIME SPECIFIED.
All Temperatures in Degrees Centigrade.

Time.		Silica.	Fire Clay		
			Heavy Duty.	Moderate Duty.	Light Duty.
Hr.	Min.				
	15	40	160	160	160
	30	80	280	280	280
	45	140	400	400	400
1	0	200	500	500	500
	15	260	620	595	570
	30	290	720	685	640
	45	300	815	770	700
2	0	310	900	850	755
	15	320	980	920	810
	30	385	1045	990	860
	45	490	1100	1050	905
3	0	590	1150	1100	950
	15	695	1195	1145	985
	30	800	1235	1185	1020
	45	900	1270	1220	1050
4	0	1000	1300	1250	1075
	15	1100	1330	1275	1090
	30	1200	1350	1300	1100
	45	1250	1350	1300	1100
5	0	1300	1350	1300	1100
	15	1350	1350	1300	1100
	30	1380	1350	1300	1100
	45	1410	1350	1300	1100
6	0	1440	1350	1300	1100
	15	1470	End	End	End
	30	1500			
	45	1500			
7	0	1500			
	15	1500			
	30	1500			
	45	1500			
8	0	1500			
		End			

The test specimen shall be measured before testing, making not less than five observations in each direction to within ±0.02 in. (0.5 mm.). The average dimensions shall be reported, and the cross-section calculated.

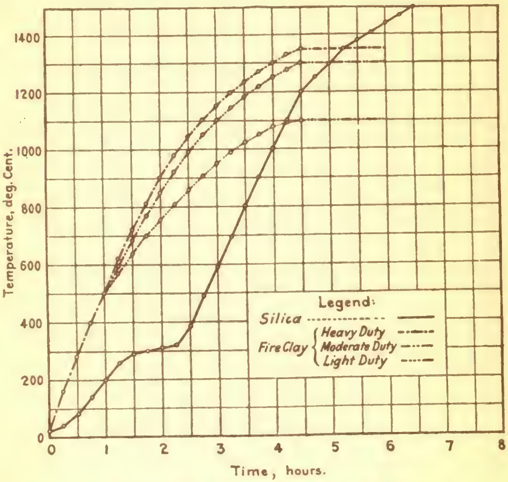


FIG. 3.—Time-Temperature Curve for Load Test.

Starting the Test.

4. The test specimen shall occupy approximately the center of the furnace and should rest on a block of some highly refractory material, having a minimum expansion or contraction. A silicon-carbide brick has been found satisfactory. At the top of the test specimen a block of similar highly refractory material should be placed, extending through the furnace top to receive the load.

NOTE.—Gross errors which may more than double the contraction will result if the specimen is not set perpendicular to the base of the support or if the load is eccentrically applied.

Heating.

5. The rate of heating shall be in accordance with the requirements of Table I and the time-temperature curves of Fig. 3, which give the rate and time of heating suggested for different grades of material.

Loading.

6. (*a*) The load is calculated from the average cross-section as determined on the untested specimen and the requirement of the test. It is recommended that for general purposes, 25 lb. per sq. in. (1.765 kg. per sq. cm.) be used.

(*b*) The additional masses required to give the desired loading should be equally distributed on each side of the beam.

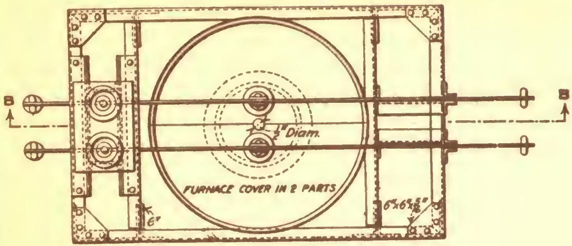
Completing the Test.

7. (*a*) At the expiration of the time of heating, the supply of heat shall be stopped and the furnace allowed to cool, during not less than 5 hours before removing the load and examining the test specimen.

NOTE.—The specimen shall be examined immediately after the heating is stopped for evidences of cracking and spalling as such defects may develop later due to the rapid cooling of the furnace.

(*b*) After the test specimen has cooled to the room temperature, it shall be remeasured as before described, and the change in length recorded and reported as percentage of the original length.

NOTE.—It is recommended that a photograph be made of the specimen before and after testing, as yielding valuable information at a minimum time and expense.



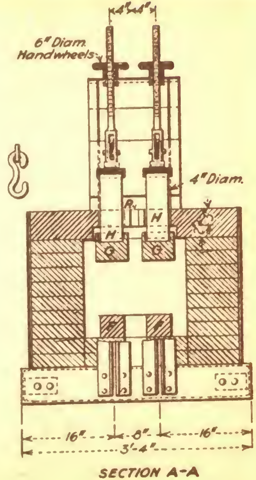


PLATE IV. 1921 AM SOC. TEST. MATS. STANDARDS

STANDARD METHOD OF
TEST FOR REFRACTORY MATERIALS.

FIG. 1.—Apparatus for Testing Refractory Materials under Load at High Temperatures.
(By courtesy of *Metallurgical and Chemical Engineering*.)

PLATE IV. 1921 AM. SOC. TEST. MATS. STANDARDS

STANDARD METHOD OF TEST FOR REFRACTORY MATERIALS.

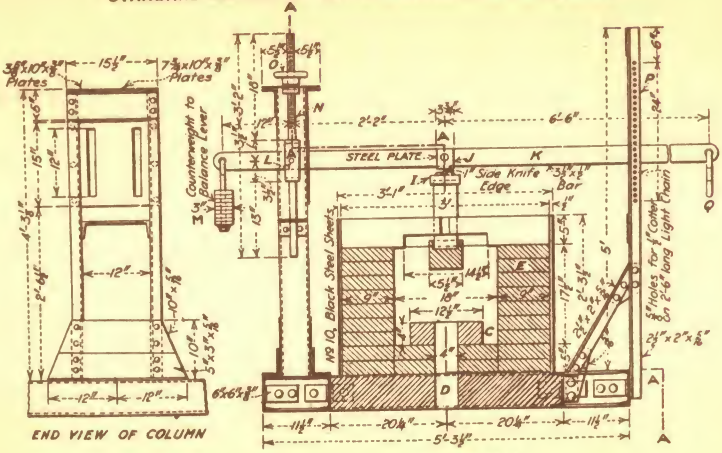


FIG. 1.—Apparatus for Testing Refractory Materials under Load at High Temperatures.
(By courtesy of *Metallurgical and Chemical Engineering*.)

STANDARD METHOD OF TEST FOR POROSITY AND PERMANENT VOLUME CHANGES IN REFRACTORY MATERIALS.

AS ADOPTED BY

AMERICAN SOCIETY FOR TESTING MATERIALS

AND REPRINTED WITH ITS PERMISSION

Serial Designation: C 20—20.

This method is issued under the fixed designation C 20; the final number indicates the year of original adoption, as standard or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1918; ADOPTED, 1920.

Object.

1. The object of this test is to determine the porosity and permanent volume changes in refractory materials when heated to series of specified temperatures.

Preparations of Test Specimens.

2. (*a*) The sample shall consist of at least seven standard-size bricks.

(*b*) Test specimens measuring 2½ by 2½ by 1¼ in. shall be cut so as to remove the original surfaces of the bricks; for this a "cut off" grinding wheel is recommended. There should be five test specimens for each of the seven heat treatments specified in Section 4 or 35 test specimens for each kind of brick The test specimens shall be brushed or washed free from all adhering dust and marked serially with a refractory stain, for which 5-per-cent cobalt-kaolin mixture is suggested.

Procedure.

3. After the test specimens have been cut and cleaned, they shall be dried and the volumes and porosity of each obtained as described in Sections 5 and 6. They shall be heated as specified in Section 4, and the changes in volume and porosity determined.

Burning.

4. (*a*) Dry the test pieces prior to placing in the kiln.

(*b*) Raise the temperature as rapidly as is consistent with even heat distribution to 1200° C. From 1200° C. raise the temperature at the rate of 30° per hour, drawing samples at each 50° interval from 1200° to 1500° C.

(*c*) If it is possible, and the number of brands being tested warrant, it is best that separate burns to each temperature be made and the kiln sealed and allowed to cool by radiation. In case separate

burns cannot be made, the five test specimens from each temperature increment should be covered with hot sand immediately on being drawn; or placed in a supplementary furnace and kept at about 500° C. until all drawings are completed, and then cooled with the furnace sealed to cool wholly by radiation.

Method of Obtaining Data.

5. (*a*) The test specimens shall be cleaned from adhering or loosely attached pieces and particles, care being taken not to alter the exterior volume as originally prepared for this test.

(*b*) The test specimens shall be heated if necessary to 110° C. to remove moisture, and their dry weight (D) obtained to 0.10 g.

(*c*) The test specimens shall be placed in kerosene of known density (δ) under a vacuum of 24 in. for 4 hours at 25° C. and cooled to room temperature while yet immersed.

(*d*) When cool, each test specimen shall be weighed suspended in kerosene at 25° C. to determine its "*suspended weight*" (S), in grams.

(*e*) The "*saturated weight*" (W), in grams, of each test specimen shall be obtained immediately after obtaining the suspended weight, by drying lightly with a kerosene-moistened towel to remove the excess kerosene and then weighing in air.

(*f*) The *Exterior Volume* (V), in cubic centimeters, of each test specimen is obtained by subtracting the suspended weight (S) from the saturated weight (W), and dividing by the density (δ) of the kerosene. Thus:

$$V = \frac{W - S}{\delta} \quad \text{.......................} (1)$$

(*g*) The *Actual Volume of Open Pores* (V_1), in cubic centimeters, is obtained by substracting the dry weight (D) from the saturated weight (W), and dividing by the density (δ) of the kerosene. Thus.

$$V_1 = \frac{W - D}{\delta} \quad \text{.......................} (2)$$

(*h*) The *Apparent Specific Gravity* (T_1) of that portion of the test specimen which is impervious to liquid is obtained by dividing the dry weight by the difference between the dry and suspended weights, and multiplying by the density of the kerosene. Thus:

$$T_1 = \frac{D}{D - S}\delta \quad \text{.......................} (3)$$

(*i*) The *True Specific Gravity* (T) of the wholly solid or burned clay portion is obtained by crushing a portion of the dried test specimen to 120-mesh powder and determining the displacement at 25° C. under 24 in. vacuum, of a 20-g. sample in a 50-cc. straight-wall pyknometer using kerosene, and correcting for density of the kerosene.

(*j*) The *Volume of Sealed Pores* (V_2), in cubic centimeters, is obtained by subtracting the quotient of dry weight (D) divided by true specific gravity (T) from the volume of the impervious portion of the test specimen ; or

$$V_2 = \frac{(D-S)}{\delta} - \frac{D}{T} \quad\text{.......................}(4)$$

(*k*) The *Volume Shrinkage* is obtained by subtracting the volumes, that is, the values of $\frac{W-S}{\delta}$, before and after the heat treatment.

Basis of Reference for the Data.

6. To show progressive changes in the several volumes, refer all volumes back to the original exterior volume of the test specimen as 100. This is done by multiplying all volumes by the factor $100 / V$, in which V is the exterior volume of the test specimen prior to the subjection to heat treatment.

The volume data should be determined for each test specimen and multiplied by the above factor to reduce all volumes for each test specimen to terms of 100 original exterior volumes of that test specimen before the average of the five for each heat treatment is calculated.

STANDARD METHOD OF TEST FOR

SOFTENING POINT OF FIRE CLAY BRICK.

AS ADOPTED BY

AMERICAN SOCIETY FOR TESTING MATERIALS

AND REPRINTED WITH ITS PERMISSION

Serial Designation: C 24—20.

This method is issued under the fixed designation C 24; the final number indicates the year of original adoption as standard, or in the case of revision, the year of last revision.

PROPOSED AS TENTATIVE, 1919; ADOPTED 1920.

Object.

1. The object of this test is to determine the softening point of fire-clay brick, by comparison of test cones with standard Orton pyrometric cones heated in a suitable furnace.

Preparation of Sample.

2. A 1-kg. (2-lb.) sample shall be taken by chipping off approximately equal portions from the corners of the brick. These fragments shall be reduced in size by means of rolls or a jaw crusher adjusted to pass a lump 6 mm. (¼ in.) in diameter. They shall be mixed thoroughly, and the amount of material reduced to about 250 g. (5-lb.) by quartering. A magnet shall be repeatedly passed through the crushed material until all particles of metallic iron are removed. This portion shall be ground in a porcelain or agate mortar to pass a 60-mesh Standard sieve.[1] In order to avoid excessive reduction of the fines, they shall be removed frequently during the process of reduction by throwing the sample on the sieve and continuing the grinding of the coarser particles until all the sample will pass through the sieve.

Preparation of Test Cones.

3. (*a*) The sample thus prepared shall be thoroughly mixed and after the addition of sufficient dextrine or glue and water, shall be formed into test cones in a metal mould in the shape of tetrahedrons measuring 5 mm. (3/16 in.) on the sides at the base and 25 mm. (1 in.) high.

[1] Diameter of wire 0.185 mm., opening 0.25 mm.

(*b*) When dry the test cones may be subjected to a preliminary burn at a temperature not exceeding 1300° C. (2372° F.) for the purpose of sintering them into a firm condition to permit handling.

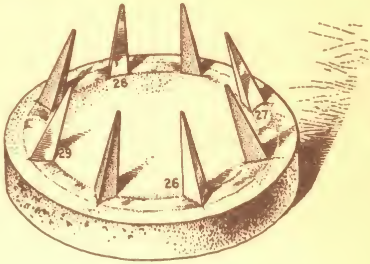


FIG. 1.

Mounting.

4. The test cones shall be mounted on plaques of refractory material of such a composition as will not affect the fusibility of the cones.[1] They shall be mounted with the base embedded approximately 1 mm. (0.04 in.) in the plaque and the face of one side inclined at an angle of 75 deg. with the horizontal. The arrangement with respect to the Orton cones shall be substantially as shown in Fig. 1, that is, alternating with the Orton cones in such a way that Orton cones of successive numbers will be placed opposite each other. The plaque may be any convenient size and shape and may be biscuited before using, if desired.

Heating.

5. (*a*) The heating shall be done in a suitable furnace at a rate not greater than 15° C. (27° F.) per minute, not less than 10° C. (18° F.) per minute after cone No. 1 is reached, or as nearly within these limits as possible.

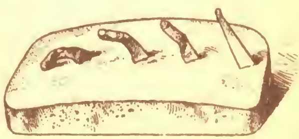


FIG. 2.

(*b*) That type of furnace in which a neutral or oxidizing atmosphere may be maintained is to be preferred. Excessive reducing conditions should be avoided. Care should be taken that the flame

[1] A mixture of equal parts of highly refractory clay, such as a good grade of china clay, and fused alumina which will pass a 100-mesh sieve, has been found satisfactory.

does not strike directly against the cone or cone plaque. The furnace should be tested at intervals for the determination of the uniformity of the distribution of the heat.

Softening Point.

6. (*a*) The softening of the cone will be indicated by the top bending over and assuming the position shown in Fig. 2. The bloating, squatting or unequal fusion of small constituent particles should always be reported. The softening point shall be reported in terms of Orton cones and shall be that cone which most nearly corresponds in time of softening with the test cone. If the test cone softens later than one Orton cone but earlier than the next Orton cone and approximately midway between, the softening point shall be reported thus: Cone No. 31-32.

(*b*) If the test cone starts bending at an early cone but is not down until a later cone, the fact should be reported.

TEMPERATURE CONVERSION TABLE

BY ALBERT SAUVEUR

—459.4 to 0

C.		F.
—273	**—459.4**	
—268	**—450**	
—262	**—440**	
—257	**—430**	
—251	**—420**	
—246	**—410**	
—240	**—400**	
—234	**—390**	
—229	**—380**	
—223	**—370**	
—218	**—360**	
—212	**—350**	
—207	**—340**	
—201	**—330**	
—196	**—320**	
—190	**—310**	
—184	**—300**	
—179	**—290**	
—173	**—280**	
—169	**—273**	—459.4
—168	**—270**	—454
—162	**—260**	—436
—157	**—250**	—418
—151	**—240**	—400
—146	**—230**	—382
—140	**—220**	—364
—134	**—210**	—346
—129	**—200**	—328
—123	**—190**	—310
—118	**—180**	—292
—112	**—170**	—274
—107	**—160**	—256
—101	**—150**	—238
— 95.6	**—140**	—220
— 90.0	**—130**	—202
— 84.4	**—120**	—184
— 78.9	**—110**	—166
— 73.3	**—100**	—148
— 67.8	**— 90**	—130
— 62.2	**— 80**	—112
— 56.7	**— 70**	— 94
— 51.1	**— 60**	— 76
— 45.6	**— 50**	— 58
— 40.0	**— 40**	— 40
— 34.4	**— 30**	— 22
— 28.9	**— 20**	— 4
— 23.3	**— 10**	14
— 17.8	**— 0**	32

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
0.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

NOTE.—The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right. These tables are a revision of those by Sauveur & Boylston, metallurgical engineers, Cambridge, Mass. Copyright, 1920.

TEMPERATURE CONVERSION TABLE—Cont.

By Albert Sauveur

0 to 100

C.		F.	C.		F.
—17.8	**0**	32	10.0	**50**	122.0
—17.2	**1**	33.8	10.6	**51**	123.8
—16.7	**2**	35.6	11.1	**52**	125.6
—16.1	**3**	37.4	11.7	**53**	127.4
—15.6	**4**	39.2	12.2	**54**	129.2
—15.0	**5**	41.0	12.8	**55**	131.0
—14.4	**6**	42.8	13.3	**56**	132.8
—13.9	**7**	44.6	13.9	**57**	134.6
—13.3	**8**	46.4	14.4	**58**	136.4
—12.8	**9**	48.2	15.0	**59**	138.2
—12.2	**10**	50.0	15.6	**60**	140.0
—11.7	**11**	51.8	16.1	**61**	141.8
—11.1	**12**	53.6	16.7	**62**	143.6
—10.6	**13**	55.4	17.2	**63**	145.4
—10.0	**14**	57.2	17.8	**64**	147.2
— 9.44	**15**	59.0	18.3	**65**	149.0
— 8.89	**16**	61.8	18.9	**66**	150.8
— 8.33	**17**	63.6	19.4	**67**	152.6
— 7.78	**18**	65.4	20.0	**68**	154.4
— 7.22	**19**	67.2	20.6	**69**	156.2
— 6.67	**20**	68.0	21.1	**70**	158.0
— 6.11	**21**	69.8	21.7	**71**	159.8
— 5.56	**22**	71.6	22.2	**72**	161.6
— 5.00	**23**	73.4	22.8	**73**	163.4
— 4.44	**24**	75.2	23.3	**74**	165.2
— 3.89	**25**	77.0	23.9	**75**	167.0
— 3.33	**26**	78.8	24.4	**76**	168.8
— 2.78	**27**	80.6	25.0	**77**	170.6
— 2.22	**28**	82.4	25.6	**78**	172.4
— 1.67	**29**	84.2	26.1	**79**	174.2
— 1.11	**30**	86.0	26.7	**80**	176.0
— 0.56	**31**	87.8	27.2	**81**	177.8
0.	**32**	89.6	27.8	**82**	179.6
0.56	**33**	91.4	28.3	**83**	181.4
1.11	**34**	93.2	28.9	**84**	183.2
1.67	**35**	95.0	29.4	**85**	185.0
2.22	**36**	96.8	30.0	**86**	186.8
2.78	**37**	98.6	30.6	**87**	188.6
3.33	**38**	100.4	31.1	**88**	190.4
3.89	**39**	102.2	31.7	**89**	192.2
4.44	**40**	104.0	32.2	**90**	194.0
5.00	**41**	105.8	32.8	**91**	195.8
5.56	**42**	107.6	33.3	**92**	197.6
6.11	**43**	109.4	33.9	**93**	199.4
6.67	**44**	111.2	34.4	**94**	201.2
7.22	**45**	113.0	35.0	**95**	203.0
7.78	**46**	114 8	35.6	**96**	204.8
8.33	**47**	116 6	36.1	**97**	206.6
8.89	**48**	118.4	36.7	**98**	208.4
9.44	**49**	120.2	37.2	**99**	210.2
			37.8	**100**	212.0

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
0.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

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TEMPERATURE CONVERSION TABLE—Cont.

By Albert Sauveur

100 to 1000

C.		F.	C.		F.
38	**100**	212	260	**500**	932
43	**110**	230	266	**510**	950
49	**120**	248	271	**520**	968
54	**130**	266	277	**530**	986
60	**140**	284	282	**540**	1004
66	**150**	302	288	**550**	1022
71	**160**	320	293	**560**	1040
77	**170**	338	299	**570**	1058
82	**180**	356	304	**580**	1076
88	**190**	374	310	**590**	1094
93	**200**	392	316	**600**	1112
99	**210**	410	321	**610**	1130
100	**212**	413	327	**620**	1148
104	**220**	428	332	**630**	1166
110	**230**	446	338	**640**	1184
116	**240**	464	343	**650**	1202
121	**250**	482	349	**660**	1220
127	**260**	500	354	**670**	1238
132	**270**	518	360	**680**	1256
138	**280**	536	366	**690**	1274
143	**290**	554	371	**700**	1292
149	**300**	572	377	**710**	1310
154	**310**	590	382	**720**	1328
160	**320**	608	388	**730**	1346
166	**330**	626	393	**740**	1364
171	**340**	644	399	**750**	1382
177	**350**	662	404	**760**	1400
182	**360**	680	410	**770**	1418
188	**370**	698	416	**780**	1436
193	**380**	716	421	**790**	1454
199	**390**	734	427	**800**	1472
204	**400**	752	432	**810**	1490
210	**410**	770	438	**820**	1508
216	**420**	788	443	**830**	1526
221	**430**	806	449	**840**	1544
227	**440**	824	454	**850**	1562
232	**450**	842	460	**860**	1580
238	**460**	860	466	**870**	1598
243	**470**	878	471	**880**	1616
249	**480**	896	477	**890**	1634
254	**490**	914	482	**900**	1652
			488	**910**	1670
			493	**920**	1688
			499	**930**	1706
			504	**940**	1724
			510	**950**	1742
			516	**960**	1760
			521	**970**	1778
			527	**980**	1796
			532	**990**	1814
			538	**1000**	1832

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
0.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

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TEMPERATURE CONVERSION TABLE—Cont.

By Albert Sauveur

1000 to 2000

C.		F.	C.		F.
538	**1000**	1832	816	**1500**	2732
543	**1010**	1850	821	**1510**	2750
549	**1020**	1868	827	**1520**	2768
554	**1030**	1886	832	**1530**	2786
560	**1040**	1904	838	**1540**	2804
566	**1050**	1922	843	**1550**	2822
571	**1060**	1940	849	**1560**	2840
577	**1070**	1958	854	**1570**	2858
582	**1080**	1976	860	**1580**	2876
588	**1090**	1994	866	**1590**	2894
593	**1100**	2012	871	**1600**	2912
599	**1110**	2030	877	**1610**	2930
604	**1120**	2048	882	**1620**	2948
610	**1130**	2066	888	**1630**	2966
616	**1140**	2084	893	**1640**	2984
621	**1150**	2102	899	**1650**	3002
627	**1160**	2120	904	**1660**	3020
632	**1170**	2138	910	**1670**	3038
638	**1180**	2156	916	**1680**	3056
643	**1190**	2174	921	**1690**	3074
649	**1200**	2192	927	**1700**	3092
654	**1210**	2210	932	**1710**	3110
660	**1220**	2228	938	**1720**	3128
666	**1230**	2246	943	**1730**	3146
671	**1240**	2264	949	**1740**	3164
677	**1250**	2282	954	**1750**	3182
682	**1260**	2300	960	**1760**	3200
688	**1270**	2318	966	**1770**	3218
693	**1280**	2336	971	**1780**	3236
699	**1290**	2354	977	**1790**	3254
704	**1300**	2372	982	**1800**	3272
710	**1310**	2390	988	**1810**	3290
716	**1320**	2408	993	**1820**	3308
721	**1330**	2426	999	**1830**	3326
727	**1340**	2444	1004	**1840**	3344
732	**1350**	2462	1010	**1850**	3362
738	**1360**	2480	1016	**1860**	3380
743	**1370**	2498	1021	**1870**	3398
749	**1380**	2516	1027	**1880**	3416
754	**1390**	2534	1032	**1890**	3434
760	**1400**	2552	1038	**1900**	3452
766	**1410**	2570	1043	**1910**	3470
771	**1420**	2588	1049	**1920**	3488
777	**1430**	2606	1054	**1930**	3506
782	**1440**	2624	1060	**1940**	3524
788	**1450**	2642	1066	**1950**	3542
793	**1460**	2660	1071	**1960**	3560
799	**1470**	2678	1077	**1970**	3578
804	**1480**	2696	1082	**1980**	3596
810	**1490**	2714	1088	**1990**	3614
			1093	**2000**	3632

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
0.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

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TEMPERATURE CONVERSION TABLE—Cont.

BY ALBERT SAUVEUR

2000 to 3000

C.		F.	C.		F.
1093	**2000**	3632	1371	**2500**	4532
1099	**2010**	3650	1377	**2510**	4550
1104	**2020**	3668	1382	**2520**	4568
1110	**2030**	3686	1388	**2530**	4586
1116	**2040**	3704	1393	**2540**	4604
1121	**2050**	3722	1399	**2550**	4622
1127	**2060**	3740	1404	**2560**	4640
1132	**2070**	3758	1410	**2570**	4658
1138	**2080**	3776	1416	**2580**	4676
1143	**2090**	3794	1421	**2590**	4694
1149	**2100**	3812	1427	**2600**	4712
1154	**2110**	3830	1432	**2610**	4730
1160	**2120**	3848	1438	**2620**	4748
1166	**2130**	3866	1443	**2630**	4766
1171	**2140**	3884	1449	**2640**	4784
1177	**2150**	3902	1454	**2650**	4802
1182	**2160**	3920	1460	**2660**	4820
1188	**2170**	3938	1466	**2670**	4838
1193	**2180**	3956	1471	**2680**	4856
1199	**2190**	3974	1477	**2690**	4874
1204	**2200**	3992	1482	**2700**	4892
1210	**2210**	4010	1488	**2710**	4910
1216	**2220**	4028	1493	**2720**	4928
1221	**2230**	4046	1499	**2730**	4946
1227	**2240**	4064	1504	**2740**	4964
1232	**2250**	4082	1510	**2750**	4982
1238	**2260**	4100	1516	**2760**	5000
1243	**2270**	4118	1521	**2770**	5018
1249	**2280**	4136	1527	**2780**	5036
1254	**2290**	4154	1532	**2790**	5054
1260	**2300**	4172	1538	**2800**	5072
1266	**2310**	4190	1543	**2810**	5090
1271	**2320**	4208	1549	**2820**	5108
1277	**2330**	4226	1554	**2830**	5126
1282	**2340**	4244	1560	**2840**	5144
1288	**2350**	4262	1566	**2850**	5162
1293	**2360**	4280	1571	**2860**	5180
1299	**2370**	4298	1577	**2870**	5198
1304	**2380**	4316	1582	**2880**	5216
1310	**2390**	4334	1588	**2890**	5234
1316	**2400**	4352	1593	**2900**	5252
1321	**2410**	4370	1599	**2910**	5270
1327	**2420**	4388	1604	**2920**	5288
1332	**2430**	4406	1610	**2930**	5306
1338	**2440**	4424	1616	**2940**	5324
1343	**2450**	4442	1621	**2950**	5342
1349	**2460**	4460	1627	**2960**	5360
1354	**2470**	4478	1632	**2970**	5378
1360	**2480**	4496	1638	**2980**	5396
1366	**2490**	4514	1643	**2990**	5414
			1649	**3000**	5432

INTERPOLATION FACTORS

C.		F.	C.		F.
0.56	**1**	1.8	3.33	**6**	10.8
1.11	**2**	3.6	3.89	**7**	12.6
1.67	**3**	5.4	4.44	**8**	14.4
2.22	**4**	7.2	5.00	**9**	16.2
2.78	**5**	9.0	5.56	**10**	18.0

NOTE.—The numbers in bold face type refer to the temperature either in degrees Centigrade or Fahrenheit which is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right. These tables are a revision of those by Sauveur & Boylston, metallurgical engineers, Cambridge, Mass. Copyright, 1920.

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THE METALLURGISTS AND CHEMISTS' HANDBOOK
Compiled by Donald M. Liddell, C. E.

Calorific and Evaporative Values of Various Liquid Fuels[1]

	Sp. gr.	Flash point, °F.	Calorific value by bomb calories	Actual evaporation from and at 212°F.
American residuum	0.886	350	10,904	15.0
Russian Astatki	0.956	308	10,800	14.8
Texas	0.945	244	10,700	14.79
Burma	0.920	230	10,480	14.5
Borneo	0.936	285	10,461	14.0
Mexican crude	0.950	290	10,500	14.90
Oklahoma	0.863	....	10,800	....
Roumanian residue	0.946	....	10,500	....
Trinidad crude	0.945	....	10,200	....
California	0.962	....	10,400	....
Shale oil	0.875	288	10,120	13.8
Blast furnace oil	0.979	206	8,933	12.0
Heavy tar oil	1.084	218	8,916	12.0
Gasoline	0.7100	....	11,733	....
Ohio crude	0.8048	....	11,149	....

[1] Specially compiled for "The Petroleum Year Book, 1914."

Baume Gravity and Corresponding Specific Gravities, Weights per Gallon and Calorific Power of Oil[1]

Baumé°	Specific gravity	Pounds in a gallon	Calculated B.t.u. per lb.	Calculated B.t.u. per gallon	Remarks
14	0.9722	8.10	18,810	152,361	Mexico, California, Texas and Kansas crudes fuel oil
15	0.9655	8.05	18,850	151,743	
16	0.9589	7.99	18,890	150,931	
17	0.9523	7.94	18,930	150,304	
18	0.9459	7.88	18,970	149,484	
19	0.9395	7.83	19,010	148,848	
20	0.9333	7.78	19,050	148,209	
21	0.9271	7.73	19,090	147,506	
22	0.9210	7.68	19,130	146,918	
23	0.9150	7.63	19,170	146,267	
24	0.9090	7.58	19,210	145,612	
25	0.9032	7.54	19,250	145,145	
26	0.8974	7.49	19,290	144,482	
27	0.8917	7.44	19,330	143,815	
28	0.8860	7.39	19,370	143,144	Kansas, Indian Territory and Illinois crudes, Penn'a. fuel, California refined fuel oil
29	0.8805	7.34	19,410	142,469	
30	0.8750	7.29	19,450	141,790	
31	0.8695	7.25	19,490	141,303	
32	0.8641	7.21	19,530	140,811	
33	0.8588	7.16	19,570	140,121	
34	0.8536	7.12	19,610	139,623	
35	0.8484	7.07	19,650	138,926	
36	0.8433	7.03	19,690	138,421	

[1] From "Fuel Oil Data," Tate-Jones & Co., Inc., furnace engineers, based on Sherman and Kraft's formula:

$$\text{B.t.u.} = 18{,}650 + 40\,(\text{Bé.}° - 10)$$

Journ. Am. Chem. Soc., October, 1908.

Baumé Gravity and Corresponding Specific Gravities, Weights per Gallon and Calorific Power of Oil[1]—Continued.

Baumé°	Specific Gravity	Pounds in a gallon	Calculated B.t.u. per lb.	Calculated B.t.u. per gallon	Remarks
37	0.8383	6.99	19,730	137,913	Ohio, Penn'a. and West Virginia crude, California and Kansas refined fuel oil
38	0.8333	6.95	19,770	137,402	
39	0.8284	6.91	19,810	136,887	
40	0.8235	6.87	19,850	136,370	
41	0.8187	6.83	19,890	135,849	
42	0.8139	6.80	19,930	135,524	
43	0.8092	6.76	19,970	134,997	
44	0.8045	6.72	20,010	134,467	
45	0.8000	6.68	20,050	133,934	
46	0.7954	6.64	20,090	133,398	Kerosene and gasoline
47	0.7909	6.60	20,130	132,858	
48	0.7865	6.57	20,170	132,517	
49	0.7821	6.53	20,210	131,971	
50	0.7777	6.49	20,250	181,423	

[1] From "Fuel Oil Data," Tate-Jones & Co., Inc., furnace engineers, based on Sherman and Kraft's formula:

$$\text{B.t.u.} = 18{,}650 + 40\ (\text{Bé.}^\circ - 10)$$

Journ. Am. Chem. Soc., October, 1908.

Ultimate Composition of Crude Oils and Coal
Crude Oil

	Sp. gr.	C	H	O
Pennsylvania	0.886	84.9	13.7	1.4
Russia (Balachny)	0.884	87.4	12.5	0.1
Russia (Balachny residuum)	0.928	87.1	11.7	1.2
Borneo	0.945	87.8	10.78	1.24
Texas	0.936	85.66	11.03	3.31
Burma	0.920	86.4	12.1	1.5

[1] From "The Petroleum Year Book, 1914."

Oxygen and Air Required for Perfect Combustion[1]

1 kilo.	Requires kilograms		Product of combustion		Nitrogen in original air kilograms
	Oxygen	Dry air	Composition	Kilograms	
C........	1.333	5.777	CO	2.333	4.444
C........	2.667	11.555	CO_2	3.667	8.888
CO.....	0.571	2.472	CO_2	1.571	1.901
H........	8.000	34.664	H_2O	9.000	26.664
CH_4...	4.000	17.332	CO_2, H_2O	2.750,2.250	13.332
C_2H_4..	3.429	14.848	CO_2, H_2O	3.143,1.286	11.419
Fe......	0.286	1.238	FeO	1.286	0.952
Fe......	0.429	1.857	Fe_2O_3	1.439	1.428
Si........	1.143	5.064	SiO_2	2.143	3.921
P........	1.290	5.586	P_2O_5	2.290	4.296
Mn.....	0.291	1.221	MnO	1.291	0.969
S........	1.000	4.333	SO_2	2.000	3.333

Theoretical Maximum Combustion Temperatures[2]

Oxyhydrogen flame..........................	3191°C.
Hydrogen and dry air......................	2010°C.
Hydrogen and dry air in 25% excess	1764°C.
Carbon monoxide with cold air......	2050°C.
CO and air, both at 700°C.............	2284°C.
Natural gas and air..........................	1806°C.
Natural gas with air at 1000°C......	2288°C.
Thermit ($2Al + Fe_2O_3$).................	2694°C.

[1] From Hofman's "General Metallurgy."
[2] J. W. Richard's "Metallurgical Calculations," Vol. I ,pp. 36-39.

Limits of Fuel Analysis—United States[1]

	H_2O	Ash	Sulphur	C	H	O + N	Calories
Peat	6.00–19.7	3.2–36.0	0.19–1.94	....	....	....	2867–5161
Brown coal	5.8 –14.0	1.7–14.7	0.63–2.20	53–70	3.6– 7.4	10.8–23.9	4700–6000
Bituminous	0.6 – 5.2	6.1–14.7	0.90–4.5	60.5–78.8	4.8– 5.2	9.1–15.4	6000–8000
Anthracite	0.5 – 2.5	1.0– ?	....	91–98	0.0– 3.0	0.0– 3.0	7000
Coke[2]	0.15– 1.2	3.8–11.5	0.6 –1.6	87–93	0.4– 3.0	....	....

[1] Somermeier's "Coal."
[2] Compressive strength of 600-2000 lb. per square inch, hardness of 2.5-3. These values from private notes on Eastern cokes.

Typical Gas Analysis[1]

	CO	Vol. hyd. carb.	N	CO_2	H
Producer gas	23.7–33.6	1.3 –11.9	49.5–67.1	0.45– 5.30	1.25– 9.7[2]
Mond gas	10.3–11.0	2.0 – 5.3	43.0–55.8	14.6 –16.5	23.5 –27.5
Iron-furnace gas	20.0–32.0	0.0 – 0.6	55.0–65.0	6.0 –18.0	1.0 – 6.0
Water gas (blow up)	23.7–32.2	0.18– 0.44	63.9–65.9	1.6 – 7.0	2.1 – 2.95
Water gas (true)	40.9–45.2	0.2 – 1.1	1.9– 7.1	1.8 – 5.6	44.8 –51.4
Oil gas	0.6– 1.8	28.5 –77.3	0	1.3	18.9 –68.5

[1] Hofman's "General Metallurgy."
[2] Using steam.

Shale Oil

These oils are secured by the distillation of shales. Two typical shale analyses are given by SEXTON as follows: (1) Volatile matter, 34.96 per cent.; fixed carbon, 7.54 per cent.; ash, 57.5 per cent. (2) Volatile matter, 13.5 per cent.; fixed carbon, 2.5 per cent.; ash, 84 per cent.[1]

Coal Burned per Square Foot of Grate in Reverberatory Furnaces[2]

Hand reverberatory roasting furnace	3 to 8 lb.
Agglomerating or lead-reverberatory smelting furnace	12 to 16 lb.
Copper-reverberatory smelting furnace	16 to 30 lb.
Puddling furnace	20 to 30 lb.
Heating furnace	30 to 40 lb.
Locomotive boilers (induced draft)	80 to 100 lb.

Ratio of Areas of Total Grate to Air Space[3]

Coke	3:1 to 2:1
Bituminous coal	3:3:1 to 2:1
Brown coal	5:1 to 3:1
Peat or wood	7:1 to 5:1

Combustion Data

Good Modern Practice

1 lb. coal average	13,500 B.t.u.
1 lb. coal $(13,500 \times 778) \div (60 \times 33,000)$	5.3 hp.-hours.
Lost through grates	1.00 per cent.
Lost boiler radiation	5.00 per cent.
Lost chimney gases	22.00 per cent.
Lost main pipes radiation	1.56 per cent.
Lost auxiliary pipes radiation	0.22 per cent.
Lost auxiliary exhaust	1.40 per cent.
Lost engine radiation	2.08 per cent.
Lost engine exhaust	57.31 per cent.
Total loss	90.57 per cent.
Converted to power	9.43 per cent.

[1] SEXTON, "Fuel and Refractory Materials."
[2] GRUNER, "Traité de Metallurgie Générale."
[3] Leitfader to Eisenhüttenkunde, 1898, p. 104.

Mineral Oils—General Composition

The characteristics of crude mineral oils and their products vary greatly in different localities; but the following general information may be of interest.

	Gravity, deg. Bé.	Flash point, deg. F.	Burning point deg. F.
Crude oil	12–45	110–200	120–220
Kerosene	40–50	90–125	105–150
Distillate (gas oil)	28–38	100–250	110–325
Fuel oil	22–28	100–300	125–375
Residuum	10–20	125–500	200–600

The heat value of mineral oils and their products may be very closely determined from their gravity, by the following formula:

$$\text{B. t. u. per pound} = 18{,}650 + \left\{40(\text{Baumé} - 10)\right\}$$

(SHERMAN AND KRAPFF)

COAL[2]

	Sp. gr.	C	H	O	S	Ash	H_2O
Welsh	1.315	83.8	4.8	1.0	1.4	4.1	4.9
Newcastle.	1.256	82.1	5.3	1.3	1.2	5.7	3.8
Lancashire	1.273	77.9	5.3	1.3	1.4	9.5	4.6

COMPARATIVE COMPOSITION OF DIFFERENT FUELS[3]

Moisture Content when New

Fuel	Moisture per cent.	Remarks
Wood	30–60	Green wood.
Peat	50–90	As dug.
Lignite	30–45	As mined.
Bituminous coal	2–25	As mined.
Semi-bituminous coal	1– 5	As mined.
Anthracite coal	1– 3	As mined.

[1] "The Diesel Engine," BUSCH-SULZER BROS., Diesel Engine Co.
[2] "Petroleum Year Book," 1914.
[3] SOMERMEIER'S "Coal."

Hints on Brick Laying

Always store Refractories in a Dry Place

The composition of the fire clay in which brick are laid should be, if possible, the same as the brick themselves, and the brick should be dipped in a thin paste and laid, not laid in a mortar. In general, the thinner the bond between the bricks the better the work. The joints are the zones of greatest weakness and are soonest attacked. For metallurgical furnaces it appears that the denser the brick the less its absorption. Magnesite brick are best laid in a suspension of finely ground magnesite in anhydrous tar, or magnesite and linseed oil, or in a suspension of magnesite in a 20 per cent. sodium silicate solution. Silica brick are best laid in a thin paste of 60 fine sand, 40 fire-clay. About $\frac{5}{32}$ in. per foot should be left for expansion in a furnace bottom.

Magnesite bricks are good conductors of heat, and where this conductivity would injure the armoring of the furnace, the brick should be backed by asbestos or some other non-conductor. Great variations of temperature, or heating when they are moistened with water or oil, will cause spalling. Magnesite brick should not be subjected to great loads when hot.

For red-brick work 9 cu. ft. of sand and 3 bu. of lime will lay 1000 brick.

M. S. Wologdine has probably done the west work on the thermal properties of fire brick. A. L. Queneau deduces, among others, the following conclusions from Wologdine's work:

1. All terra cotta, building bricks and fire bricks have practically equal coefficients of heat conductivity. The coefficients are differentiated in this class of refractory materials solely by the temperature of burning and not by the character of the clays or by their chemical composition.

2. In all refractory materials, including the special bricks, such as chrome, magnesia, carborundum and graphite, the heat conductivity is a direct function of the temperature of burning.

3. The coefficient of heat conductivity of chrome brick is practically independent of the temperature.

4. There are remarkable variations in the permeability to gases of the same bricks with increase in temperature. In one case the permeability changed from 3.3 liters per hour to 241 liters per hour. This shows the importance of scientifically selecting the clay mixtures for a given work as for crucibles or retorts where, as in zinc metallurgy, the permeability to gases has a material influence on the metal recovery. In this connection the nil permeability of graphite crucibles is to be noted. Perhaps the same results might be obtained at a much reduced cost by substituting clay flakes for the graphite flakes proposed by H. PUTZ (German pat. 198,840 of Sept. 29, 1907).

5. To secure efficient heat insulation, refractory materials should be burned at the lowest allowable temperature. This burning temperature is generally known; it is the maximum temperature to which the bricks will be exposed in the furnaces. The use of the maximum temperature is necessary in order to prevent the brick from shrinking any further when set in the furnace walls. Though this last fact is well known it is often neglected, and a shortening of the furnace life is the result.

6. The gas permeability of the bricks of blast-furnace linings must have an important bearing on their life, owing to the destructive action of carbon monoxide in contact with the iron oxide present in the brick.

There is no question that the absorption of metals by a furnace bottom will be directly proportional to the air spaces in the original brick; consequently in work with any of the non-ferrous metals, the nearer the ratio of the specific gravity of the brick in bulk to the true specific gravity of the constituent material approaches unity, the better the brick.

Short Description of the Common Refractories

Alundum.—Melting point, 2050°C.; specific heat, 0.195–01.98 at 100°C.; thermal conductivity about twice that of fire brick. Electric resistivity, at 528°C., 130 megohms per cc.; at 730°, 16 megohms; at 892°, 5.3 megohms; at 1020°, 1.8 megohms. Coefficient of expansion, 0.0000071 per deg. C.; maximum crushing strength, 7½ tons per square inch; tensile strength, 1700 lb. per square inch. Specific gravity, 3.91.

Asbestos.—A very poor conductor of heat and refractory, but will not stand molten slags. The composition of a typical Canadian asbestos is: MgO, 40.07; FeO, 0.87; Al_2O_3, 3.67; SiO_2, 39.05, H_2O, 14.48; total, 98.14%.

Bauxite.—Bauxite melts at 1820°C., but as bauxite shrinks about 30 per cent. and crumbles in calcining, some silica must be added to make a good brick. The washed bauxite is calcined at from 1350° to 1400°, ground, pugged with about 4 per cent. of a highly aluminous plastic clay, balled, dried and calcined. The mixture is then ground, pugged again with clay and hand molded. Basic open-hearth brick should not contain over 12 per cent. of silica. An analysis of an American bauxite brick is: SiO_2, 2 per cent.; TiO_2, 5 per cent.; Al_2O_3, 90.5 per cent.; Fe_2O_3, 1 per cent.; and CaO, 1.5-2 per cent. The crushing strength may be as high as 10,000 lb. per square inch, but in general the bricks are weak.

Bull Dog.—This is a mixture of ferric oxide and silica made by roasting tap cinder with free access of air. Tap cinder is a basic ferrous silicate—$2FeO\text{-}SiO_2$ or thereabouts—and on roasting it takes up oxygen, and gives a mixture of ferric oxide and silica. As these do not unite, the substance is infusible in an oxidizing atmosphere, but fuses in a reducing atmosphere, ferrous silicate being re-formed.[1]

Chrome.—Typical chromites used for refractories analyze as follows (*Eng. and Min. Journ.*, Oct. 24, 1908): Turkish: Cr_2O_3, 51.70 per cent.; FeO, 14.20; Al_2O_3, 14.10; MgO, 14.30; SiO_2, 3.50; CaO, 1.70; H_2O, 0.30 per cent.; New Caledonian: Cr_2O_3, 55.70 per cent.; FeO, 16.60; Al_2O_3, 18.20; MgO, 9.80; SiO_2, 0.25; CaO, 0.25; MnO, 0.20; P_2O_5, 0.05; H_2O, 1.05 per cent.; Japanese: Cr_2O_3, 44.55 per cent.; FeO, 15.25; SiO_2, 5.4; CaO, 0.20; MgO, 19.10; Al_2O_3, 15.20; H_2O, 0.30 per cent. Chrome is unreliable above 1500°C.

[1] SEXTON, "Fuel and Refractory Materials."

Conducts heat two to four times as well as clay brick. Makes a good breaking joint between magnesite and silica. Should be used as little as possible in furnace bottoms on lead, copper, silver, or gold work, as the cobbing is almost impossible either to grind or to smelt. It is not so strong as alumina, nor so resistant to high temperatures.

Crystolon.—Crystallized silicon carbide (SiC)—does not fuse at 2700°C. Conducts heat a little better than alundum (*q.v.*). Electric resistivity, at 320°C., 31.8 megohms per cc.; at 650°C., 6.3 megohms; at 809° C., 3.2 megohms; at 940°C., 1.0 megohms; at 1040°C., 0.4 megohms. It is not affected by acids or acid vapors, except hydrofluoric, but reacts readily with alkalis, alkaline carbonates and alkaline sulphates, and, at elevated temperatures, with the oxides of practically all metals. Coefficient of expansion, 0.0000045 per deg. C.

Dinas brick—a classic English brick made in South Wales. Composition: SiO_2, 96.80 per cent.; Al_2O_3, 0.92; Fe_2O_3, 0.50; CaO, 1.20; alkalis, 0.20. It is essentially a silica brick with lime as a binder. In America this is known as ganister.

Dolomite.—Analyses of typical dolomites (from HARBORD'S "Steel," p. 212) are: Raw, SiO_2, 1.10 per cent.; Fe_2O_3 and Al_2O_3, 1.64; CaO, 33.20; MgO, 19.60; CO_2, 44.30 per cent. Calcined, SiO_2, 3.66 per cent.; Fe_2O_3 and Al_2O_3, 4.80; CaO, 55.50; MgO, 34.83; CO_2, 1.06 per cent.

Fibrox—a fibrous silicon oxycarbide, formed in the presence of certain catalytic agents, of which calcium fluoride is one, by the reaction between vapors of silicon and carbon monoxide or dioxide. It is a soft, resilient, fibrous material, the average diameter of the fibers being stated by E. WEINTRAUB of the General Electric Co. as being about 0.6μ, or about the wave length of yellow light, or about one-twentieth that of fine cotton fibre. Its apparent weight is about 2½ to 3 grams per liter, its real specific gravity about 1.84 to 2.2. It is claimed to be the best heat insulator known. It oxidizes slowly above 1000°C.

The effect of the density on the heat resistivity of fibrox at temperatures of 200° and 500° is shown by the foregoing table.[1]

Ganister—another classic English refractory. A typical analysis, from HARBORD: SiO_2, 94.60 per cent.; Al_2O_3, 1.40; Fe_2O_3, 0.90; CaO, 0.48; MgO, 0.16; alkalis, 0.14; water, 2.60 per cent.

Lime.—FITZGERALD reports that lime fused in the electric furnace may be a very useful refractory. It is a better conductor of heat than ordinary lime. Blocks cut from it resist quick heating followed by sudden cooling. Fused lime resists exposure to moist air remarkably well, hydration being a matter of days.

Magnesite—composition, - - - - - - brick: SiO_2, 1.46 per cent.; Al_2O_3, 1.50; Fe_2O_3, 7.58; CaO, 3.14; MgO, 86.36 per cent.

Conducts heat two to four times as fast as clay brick. Usually laid dry, or in a paste made of magnesite clay and 20 per cent. water-glass solution. Magnesite can only be considered "dead-burned" when the final ignition temperature exceeds 1800°C. The greatest objection to magnesite is its cracking when heated to a high temperature. This is due to its shrinkage; a piece of magnesite heated to 350° may have a density of 3.19, while electrically fused its density will be 3.65.

Silica Sand.—An analysis of the sand used for furnace bottoms in Swansea is from (PERCY): SiO_2, 87.87 per cent.; Al_2O_3, 2.13; Fe_2O_3, 2.72; CaO, 3.79; MgO, 0.21; volatile, 2.60 per cent. Silica melts at 1750°, after softening at 1500°, and becoming glassy at 1700°C. It expands on heating and does not return exactly to its former volume. In general, silica brick are highly refractory, porous, of low specific gravity, brittle and hard to cut, poor conductors of heat, inelastic, and not resistant to sudden changes of temperature. The compressive strength is about 1900 to 4000 lb. per square inch. A typical American silica-lime brick analysed as follows: SiO_2, 93.92 per cent.; Fe_2O_3, 0.79; Al_2O_3, 3.07; CaO, 2.55; MgO, 0.18; porosity, 18.58 per cent. of volume, expansion, 0.188 in. per foot. Another brick gave 0.346 in. per foot expansion.

[1] From a paper presented at the Atlantic City Meeting, American Electrochemical Society, Apr. 22, 1915.

Siloxicon—a more or less oxidized carborundum, the amorphous crystolon of the Norton Co.

Zirconia—a pure white refractory of a density of about 5.9 and a melting point of about 2956°C. Its first important use was to replace the calcium-oxide cylinders in the DRUMMOND light. Used also in the first WELSBACH experiments. Its heat-conducting power is not over half that of firebrick. Has been used as a lining of a SIEMENS-MARTIN furnace with good results. Owing to its thermal conductivity a 2-in. lining of zirconia is equal to 4 in. of chamotte. It is practically unaffected except by molten fluarides and bisilicates.

All binding materials tend to lower the melting point of zirconia. In lining furnaces or other metallurgical apparatus, natural zirconia can be mixed with anhydrous tar as a binder, in which case wooden forms are generally used. These are allowed to remain in place and consumed during the initial heat. The temperature should be raised slowly at first, while burning out the tar, after which a temperature of at least 1400°C. must be maintained for about 48 hr. Natural zirconia begins to fuse at about 1800°C., and at about 2000°C. there is a noticeable volatilization of silica and other impurities.

In the manufacture of natural zirconia brick, muffles, crucibles, etc., about 2 per cent. of air-slacked lime as a binder has been used with success. In practice, a batch composed of 75 per cent. 100-mesh zirconia, 23 per cent. of 10 mesh, and 2 per cent. of slacked lime, is worked into a plastic with a 3 per cent. solution of 38°Bé. sodium silicate. The bricks or ware are then pressed from this and allowed to thoroughly dry in a warm atmosphere. The procedure from this point on is the same as in the burning of ordinary refractories, except that a temperature of at least 1400°C. is necessary to secure the proper vitrification.

As the density of zirconia is rather high (about 5.0), it has been suggested where imperviousness is not desired, that the incorporation of certain organic substances or volatile salts which would be destroyed during firing, thus producing small air cells, might serve to lighten the finished product without impairing its efficiency. Sawdust, cork dust or certain ammonium salts might prove of value for such aëration.

Using pure zirconium oxide with 3 to 10 per cent. of magnesia, and using starch, phosphoric acid, glycerin or borates as binders very remarkable heat-resisting ware can be manufactured. The forms are dried for several days at a low temperature and then fired in the electric furnace at 2000-2300°C. Owing to the low coefficient of expansion this ware can be plunged red-hot into water without cracking.

MELTING POINTS OF FIRE BRICK

Alumina	2100°(*e*), softens 1970 C.(*e*)
Alundum	2050°C. (*a*)
Bauxite	1820°C. (*b*)
Bauxite brick	1620-1785°C.(*a*)
Bone-ash cupel	1865° C.(*c*)
Carborundum	Decomposes at 2220° with fusing, (*b*)
Chromite	2050°C. (*a*); 2180° (*b*); 1545°–1730°.(*c*)
Clay Brick, 1st class	1555-1740°C.(*a*)
Clay brick, 2d class	1400-1650°C.(*e*)
Diatom nonpariel brick	900°C.(*d*)
Dinas silica	1680°C.(*c*)
Kaolinite (pure)	1740°C.(*b*) 1830°.(*e*)
Lime (CaO)	Softens about 2040°C.(*e*)
Magnesia	2720°C.(*a*), softens about 2500°C.(*e*)
Magnesite brick	2165°C.(*a*), softens about 2000°C.(*e*)
Silica	1700-1705°C.(*a*)
Silicon carbide	2700° + C.(*a*)

Fused silica—thermal conductivity high. Melting point, 1430°C. Sp. gr., 2.5-2.6. Specific heat, 0.776. Coefficient of expansion, 0.00000539 per deg. C.

(*a*) According to Bureau of Standards.

(*b*) *Bull. Tech. A. et M.*, July, 1913, p. 728.

(*c*) W. H. Patterson, "Brit. Iron and Steel Inst. Carnegie Scholarship Memoirs," No. 6, p. 231, 1914.

(*d*) Information from manufacturers. An insulator, not a refractory.

(*e*) F. T. Havard, "Fuels and Refractories."

International Atomic Weights, 1916

Element	Symbol	Weight	Valence[1]	Electro-chem. equivalents, g. peramp.-hr.	Melting points	Boiling points
Aluminum	Al	27.1	3	0.3368	658.7	1800.0
Antimony	Sb	120.2	3	1.4966	630.0	1460.0
Argon	A	39.88	0	....	—188.0	—186.0
Arsenic	As	74.96	3	0.9324	850.0	450.0[2]
Barium	Ba	137.37	2	2.5619	850.0	....
Bismuth	Bi	208.0	3	2.5854	271.0	1440.0
Boron	B	11.0	3	....	2350.0	....
Bromine	Br	79.92	1	2.9814	—7.3	58.75
Cadmium	Cd	112.40	2	2.0955	320.9	778.0
Caesium	Cs	132.81	1	....	26.0	....
Calcium	Ca	40.07	2	0.7477	810.0	....
Carbon	C	12.05	4	0.1118	>3600.0	....
Cerium	Ce	140.25	4	....	623.0	....
Chlorine	Cl	35.46	1	1.3220	—101.5	— 37.6
Chromium	Cr	52.0	3	0.6476	1520to >Fe	2200.0
Cobalt	Co	58.97	2	1.1000	1610[3]	....
Columbium	Cb	93.1	5	....	1950–2200	....
Copper	Cu	63.57	2	1.1858	1083.0	2100.0
Dysprosium	Dy	162.5	....	....	....	....
Erbium	Er	167.7	....	....	....	....
Europium	Eu	152.0	....	....	....	....
Fluorine	F	19.0	1	0.7085	—223.0	—187.0
Gadolinium	Gd	157.3	....	....	....	....
Gallium	Ga	69.9	....	....	30.1	....
Gernanium	Ge	72.5	....	....	958.0	....
Glucinum	Gl	9.1	....	....	1800.0	....
Gold	Au	197.2	3	2.4513	1063.0	....
Helium	He	4.002	0	....	—271.9	—268.8
Holmium	Ho	163.5	....	....	....	....
Hydrogen	H	1.008	1	0.03759	—259.0	—252.8
Indium	In	114.8	....	....	154.5	....
Iodine	I	126.92	1	4.7303	114.0	184.35
Iridium	Ir	193.1	4	....	2300.0	....
Iron	Fe	55.84	2	1.0404	1530±5	2450.0
Krypton	Kr	82.92	....	....	—169.0	—151.7
Lanthanum	La	139.0	....	....	810.0	....
Lead	Pb	207.20	2	3.8613	327.4	1525.0
Lithium	Li	6.94	1	0.2622	186.0	....
Lutecium	Lu	175.0	....	....	....	....
Magnesium	Mg	24.32	2	0.4531	651.0	1120.0
Manganese	Mn	54.93	2	1.0255	1260±20	1900.0
Mercury	Hg	200.6	2	7.4803	—38.7	357.0
Molybdenum	Mo	96.0	2	1.7900	2500.0	....
Neodymium	Nd	144.3	....	....	840.0	....
Neon	Ne	20.0	0	....	—253.0	....

[1] In those cases in which a metal has two valences, the valence given corresponds to the electrochemical equivalent, and may not necessarily be the commoner one.

[2] Sublimes. [3] Commercial metal, about 1480°C.

INTERNATIONAL ATOMIC WEIGHTS, 1916. Continued

Element	Symbol	Weight	Valence[1]	Electro-chem. equiva-lents, g. per amp.-hr.	Melting points	Boiling points
Nickel	Ni	58.68	2	1.0945	1452±3	
Niton	Nt	222.4	0			
Nitrogen	N	14.01	3	0.1745	—210.5	—195.7
Osmium	Os	190.9			2700.0	
Oxygen	O	16.00	2	0.2983	—218.0	—183.0
Palladium	Pd	106.7	2	1.9951	1550.0	
Phosphorus	P	31.04			44.1	287.0
Platinum	Pt	195.2	4	1.8206	1755.0	
Potassium	K	39.10	1	1.4584	62.3	667.0
Praseodymium	Pr	140.9			940.0	
Radium	Ra	226.0	2		900.0	
Rhodium	Rh	102.9			1940.0	
Rubidium	Rb	85.45			38.0	
Ruthenium	Ru	101.7			>1950.0	
Samarium	Sa	150.4			1350.0	
Scandium	Sc	44.1			1200.0(?)	
Selenium	Se	79.2	2	1.477	218.5	690.0
Silicon	Si	28.3	4	0.2638	1420.0	
Silver	Ag	107.88	1	4.0248	961.0	1955.0
Sodium	Na	23.00	1	0.8596	97.5	742.0
					>805,850<	
Strontium	Sr	87.63	2	1.6333	>Ca<Ba	
Sulphur	S	32.06	2	0.5980	116.5	444.5
Tantalum	Ta	181.5			2850.0	
Tellurium	Te	127.5	2	2.379	451.0	1390.0
Terbium	Tb	159.2				
Thallium	Tl	204.0			302.0	1700.0
Thorium	Th	232.4			>1700,0< Pt.	
Thulium	Tm	168.5				
Tin	Sn	118.7	2	2.2188	231.9	2270.0
Titanium	Ti	48.1	4	0.4490	1795.0±15.0	
Tungsten	W	184.0	6	1.1437	3267	
Uranium	U	238.2			Near Mo.	
Vanadium	V	51.0			1720.0±20.0	
Xenon	Xe	130.2	0		—140.0	—109.0
Ytterbium	Yb	173.5			1800.0(?)	
Yttrium	Yt	88.7			1200.0(?)	
Zinc	Zn	65.37	2	1.2194	419.3	918.0
Zirconium	Zr	90.6			2350.0(?)	

NOTE.—In addition to the above elements, there is some reason to believe in the existence of a gas 'coronium" (so called from its existence in the solar corona) which would form 0.00058 per cent. of the earth's atmosphere according to DR. A. WEGENER's calculations (*Science*, Oct. 31, 1913).

[1] In those cases in which a metal has two valences, the valence given corresponds to the electrochemical equivalent, and may not necessarily be the commoner one.

Standard Mining Screens[1]

Mesh	WireNo.	Diam. of wire, inches	Diam. of aperture, inches	Equival't in milli-meters	Per cent. of opening
1″	3	0.2437	0.7563	19.81	....
¾″	4	0.2253	0.5247	13.33	....
⅝″	5	0.2070	0.4180	10.62	....
2 mesh	8	0.1620	0.3380	8.59	....
2½	9	0.1483	0.2517	6.39	....
3	10	0.1350	0.1983	5.04	....
3½	11	0.1205	0.1652	4.20	....
4	12	0.1055	0.1445	3.67	....
4½	13	0.0915	0.1307	3.32	....
5	13	0.0915	0.1085	2.76	....
6	14	0.0800	0.0867	2.20	....
7	15	0.0720	0.0709	1.80	....
8	16	0.0625	0.0625	1.59	....
9	17	0.0540	0.0571	1.45	....
10	18	0.0475	0.0525	1.33	....
12	19	0.0410	0.0423	1.07	25.80
14	20	0.0348	0.0366	0.93	26.01
16	22	0.0286	0.0339	0.86	30.47
18	23	0.0258	0.0298	0.76	30.24
20	24	0.0230	0.0270	0.69	29.16
22	25	0.0204	0.0251	0.64	31.35
24	26	0.0181	0.0236	0.60	32.27
30	28	0.0162	0.0171	0.43	27.03
40	31	0.0132	0.0118	0.30	21.15
50	34	0.0104	0.0096	0.24	25.00
60	36	0.0090	0.0077	0.20	18.45
64	37	0.0085	0.0071	0.18	....
70	38	0.0080	0.0063	0.16	16.42
80	40	0.0070	0.0055	0.14	19.36

Rittinger's: sizes: Fine table ore, finer than 0.25 mm.; coarse table ore, 0.25-1 mm.; fine jigging ore, 1-4 mm.; coarse jigging ore, 4-16 mm.; lump ore, 16-64 mm.

[1] R. H. Richards, "Ore Dressing."

Tyler Standard Screen Scale

Ratio $\sqrt{2}$ or 1.414		Mesh	Diam. wire, dec. of an inch.
Opening in inches	Opening in millimeters		
1.050	26.67	....	0.149
0.742	18.85	....	0.135
0.525	13.33	....	0.105
0.371	9.423	....	0.092
0.263	6.680	3	0.070
0.185	4.699	4	0.065
0.131	3.327	6	0.036
0.093	2.362	8	0.032
0.065	1.651	10	0.035
0.046	1.168	14	0.025
0.0328	0.833	20	0.0172
0.0232	0.589	28	0.0125
0.0164	0.417	35	0.0122
0.0116	0.295	48	0.0092
0.0082	0.208	65	0.0072
0.0058	0.147	100	0.0042
0.0041	0.104	150	0.0026
0.0029	0.074	200	0.0021

I. M. M. Standard Laboratory Screens[1]

Mesh linear inch	Diameter of wire		Aperture		Screening area, per cent
	In.	Mm.	In.	Mm.	
5	0.1	2.540	0.1	2.540	25.00
8	0.063	1.600	0.062	1.574	24.60
10	0.05	1.270	0.05	1.270	25.00
12	0.0417	1.059	0.0416	1.056	24.92
16	0.0313	0.795	0.0312	0.792	24.92
20	0.025	0.635	0.025	0.635	25.00
30	0.0167	0.424	0.0166	0.421	24.80
40	0.0125	0.317	0.0125	0.317	25.00
50	0.010	0.254	0.01	0.254	25.00
60	0.0083	0.211	0.0083	0.211	24.80
70	0.0071	0.180	0.0071	0.180	24.70
80	0.0063	0.160	0.0062	0.157	24.60
90	0.0055	0.139	0.0055	0.139	24.50
100	0.005	0.127	0.005	0.127	25.00
120	0.0041	0.104	0.0042	0.107	25.40
150	0.0033	0.084	0.0033	0.084	24.50
200	0.0025	0.063	0.0025	0.063	25.00

[1] E. A. Smith. "Sampling and Assay of the Precious Metals."

Sizes of Round and Slot-punched Plate Screens

Needle number of screen	Approximate mesh of wire cloth to which openings correspond	Width of slot or diameter of hole in inches	Width of slot or diameter of hole in millimeters
1	12	0.058	1.47
2	14	0.049	1.25
3	16	0.042	1.07
4	18	0.035	0.89
5	20	0.029	0.74
6	25	0.027	0.69
7	30	0.024	0.61
8	35	0.022	0.56
9	40	0.020	0.51
10	50	0.018	0.46
11	55	0.0165	0.42
12	60	0.015	0.38
13	70	0.013	0.33

The needle-number is the number of the standard sewing needle that will just pass the screen.

Table taken from MacFarren's "Stamp Milling and Amalgamation".

TABLE GIVING HORSE POWER TRANSMITTED BY BELTS WHEN THE SPEED AND WIDTH OF BELTS ARE GIVEN.

From "Manuel for Engineers", Copyrighted by Charles E. Ferris, B. S.

Speed in Feet per Minute.	WIDTH OF BELT IN INCHES.											
	2 H. P.	3 H. P.	4 H. P.	5 H. P.	6 H. P.	8 H. P.	10 H. P.	12 H. P.	14 H. P.	16 H. P.	18 H. P.	20 H. P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2	3	4	5	6	8	10	12	14	16	18	20
1,000	2½	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1,200	3	4½	6	7½	9	12	15	18	21	24	27	30
1,500	3¾	5¾	7½	9½	11½	15	18¾	22½	26½	30	33¾	37½
1,800	4½	6¾	9	11¼	13½	18	22½	27	81½	36	40½	45
2,000	5	7½	10	12¼	15	20	25	30	35	40	45	50
2,400	6	9	12	15	18	24	30	36	42	48	54	60
2.800	7	10½	14	17½	21	28	35	42	49	56	63	70
3,000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3,500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4,000	10	15	20	25	30	40	50	60	70	80	90	100
4,500	11¼	17	22⅓	28	34	45	57	69	78	90	102	114
5,000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

To find the speed in feet per minute multiply the circumference of pulley, in feet, by the number of revolutions.

Blue Print Solution.—One and one-fourth ounces red prussiate of potash in eleven ounces of water; one and seven-eights ounces of citrate of ammonia in five ounces of water. Mix together and keep in dark place. Corrections can be made with a pen dipped in a solution of caustic soda; also bicarbonate of soda; also by a solution of lime.

Weight, Strength and Horse Power That Can Safely Be Transmitted With The Best Transmission Manilla Rope.

From "Manuel for Engineers", Copyrighted by Charles E. Ferris, B. S.

Diameter of rope in inches	Horse Power at 2,000 feet velocity per minute.	Horse Power at 3,000 feet velocity per minute	Horse Power at 5,000 feet velocity per minute.	Effective working tension in lbs.	Strength of Manilla rope in lbs.	Diameter of the smallest pulley at center of rope in inches.
5/8	2.42	3.63	6.05	40	4.000	18
3/4	3.62	5.43	9.05	60	5,000	22
7/8	4.94	7.41	12.35	82	7,500	26
1	6.52	9.78	16.30	108	9,000	30
1 1/4	10.10	15.15	25.25	167	14,000	37
1 1/2	14.16	21.90	36.50	242	20,250	45
1 3/4	20.00	30.00	50.00	330	30,250	52
2	26.00	39.00	65.00	430	36,000	60
2 1/4	32.90	49.35	82.25	543	49,000	68
2 1/2	40.62	60.93	101.55	670	56,250	75
3	58.50	87.75	146.25	965	81,000	90
3 1/2	79.64	119.46	199.10	1314	100,000	105

Horse Power of Finished Iron or Steel Shafting, as Prime and Second Movers Carrying Pulleys or Gears. Bearing 8 Feet from Centre to Centre for a Given Diameter and Speed.

Diameter of shaft in inches.	Revolutions per minute.	H. P. Prime Movers	H. P. Second Movers
1 7-16	100	......	3.75
1 11-16	100	......	5.95
1 15-16	100	6.40	8.88
2 3-16	100	8.10	12.65
2 7-16	100	12.50	17.35
2 11-16	100	16.00	23.10
2 15-16	100	20.00	30.00
3 3-16	100	27.00	38.13
3 7-16	100	34.00	47.63
3 11-16	100	42.00	58.58
3 15-16	100	51.00	71.11
4 3-16	100	61.00	86.57
4 7-16	100	72.00	102.66
4 11-16	100	85.00	120.67
4 15-16	100	100.00	140.63
5 3-16	100	115.00	162.71
5 7-16	100	133.00	186.97
5 11-16	100	152.00	214.54
5 15-16	100	172.00	242.52
6 7-16	100	221.00	308.09
6 15-16	100	276.00	384.54
7 7-16	100	339.00	472.67
7 15-16	100	412.00	573.38

Decimals of an Inch for each 1-64th

1-64	.015625	33-64	.515625
1-32	.03125	17-32	.53125
3-64	.046875	35-64	.546875
1-16	.0625	9-16	.5625
5-64	.078125	37-64	.578125
3-32	.09375	19-32	.59375
7-64	.109375	39-64	.609375
1-8	.125	5-8	.625
9-64	.140625	41-64	.640625
5-32	.15625	21-32	.65625
11-64	.171875	43-64	.671875
3-16	.1875	11-16	.6875
13-64	.203125	45-64	.703125
7-32	.21875	23-32	.71875
15-64	.234375	47-64	.734375
1-4	.250	3-4	.75
17-64	.265625	49-64	.765625
9-32	.28125	25-32	.78125
19-64	.296875	51-64	.796875
5-16	.3125	13-16	.8125
21-64	.328125	53-64	.828125
11-32	.34375	27-32	.84375
23-64	.359375	55-64	.859375
3-8	.375	7-8	.875
25-64	.390625	57-64	.890625
13-32	.40625	29-32	.90625
27-64	.421875	59-64	.921875
7-16	.4375	15-16	.9375
29-64	.453125	61-64	.953125
15-32	.46875	31-32	.96875
31-64	.484375	63-64	.984375
1-2	.500	1	1.

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Compiled by Donald M. Liddell, C. E.

Mathematical Constants

$e = 2.718281828459045$ $\quad \log_e 10 = 0.434294$

$\pi = \frac{355}{113}$ (approx.) $\quad e = \frac{299}{110}$ (approx.)

$\pi = 3.14159265358979$ $\quad \log \pi = 0.4971499$

$\sqrt{\pi} = 1.772$ $\quad \log_e x = 2.302585 \log_{10} x$

$\pi^2 = 9.8696$ $\quad \frac{1}{\pi_2} = 0.10132$

$\frac{1}{\pi} = 0.5642$

$\sqrt{2} = 1.4142136$ $\quad \sqrt[3]{3} = 1.4422509$

$\sqrt[3]{2} = 1.2599210$ $\quad \sqrt{5} = 2.2360680$

$\sqrt[3]{5} = 0.7937002$ $\quad \sqrt[3]{5} = 1.709621$

$\sqrt{3} = 1.7320508$

Temperature Reduction

The Fahrenheit scale is based on 212° as the boiling point of water at normal pressure, 32° as the freezing point. Its zero was formerly supposed to be the lowest temperature attainable artificially.

The Centigrade (Celsius) scale assumes the freezing point of water as being 0°, the boiling point under normal pressure as 100°.

The Reaumur scale assumes the freezing point of water as 0°, the boiling point of water as 80°.

$$\tfrac{8}{10}\,C.^\circ = R.^\circ;\ \tfrac{10}{8}\,R.^\circ = C.^\circ$$
$$\tfrac{5}{9}(F.^\circ - 32) = C.^\circ;\ \tfrac{9}{5}\,C.^\circ + 32 = F.^\circ$$
$$\tfrac{4}{9}(F.^\circ - 32) = R.^\circ;\ \tfrac{9}{4}\,R.^\circ + 32 = F.^\circ$$

Units of Heat

The British Thermal Unit (B.T.U.) is the quantity of heat required to raise the temperature of 1 lb. of water 1°F., at or near its maximum density (39.1°F.).

The calorie (Cal.) is the quantity of heat necessary to raise the temperature of 1 gram of water from 10°C. to 11°C. (sometimes also defined as "from 4°C. to 5°C.," less commonly still, from "0°C. to 1°C."

The kilogram-calorie (Cal.) is 1000 times the above.

The pound-calorie is the quantity of heat necessary to raise the temperature of 1 lb. of water 1°C. (usually from 4°C. to 5°C.).

1.0 Cal. = 3.968 B.T.U. = 2.2046 lb.-Cal.
1.0 B.T.U. = 0.252 Cal. = 778 ft.-lb.
1 lb.-Cal. = $\frac{9}{5}$ B.T.U. = 0.4536 Cal.

Latent Heat of a substance is the number of calories required to be absorbed to change 1 gram of the substance from a solid to a liquid or a liquid to a gas, without change of temperature. An equal quantity is given out when the reverse change takes place.

Specific heat of a substance is the ratio of the quantities of heat necessary to raise the temperature of equal masses of the substance and of water from the same to the same temperatures.

The equivalent points on the different scales are:

0.0° C = 0.0° R.
− 40.0° C = − 40.0° F.
− 25.6° R = − 25.6° F.

Scale of Temperatures by Color of Iron[1]

Dark red—hardly visible	970°F.	Orange	2000°F.
Dull red	1300°F.	Yellow	2150°F.
Cherry—dark	1450°F.	White heat	2350°F.
Cherry—red	1650°F.	White welding	2600°F.
Cherry—light	1800°F.	White—dazzling	2800°F.

Standard Thermometric Points[2]

Ice melts	0.0°C.	Zinc solidifies	419.4°C.
Water boils	100.0°C.	Sulphur boils	444.7°C.
Aniline boils	184.1°C.	Antimony solidifies	630.7°C.
Naphthalene boils	218.0°C.	Sodium chloride solidifies	801.0°C.
Tin solidifies	231.9°C.	Silver solidifies	960.5°C.
Benzophenone boils	306.0°C.	Copper solidifies	1083.0°C.
Lead solidifies	327.4°C.		

Weights and Measures

Linear Measure—English

12 in. = 1 ft.
3 ft. = 1 yd.
5½ yd. or 16½ ft. = 1 rod or perch
320 rods, 1760 yd., 5280 ft. = 1 mile.

[1] For tables of melting points, see pp. 128-129. For Segercone data see pp. 91-92.
[2] According to the National Physical Laboratory.

Also a number of miscellaneous units, some of which are obsolete, or obsolescent, others are used by certain trades only.

A point	= $\frac{1}{72}$ in.
A line	= $\frac{1}{12}$ in.
A barleycorn	= $\frac{1}{3}$ in.
A palm	= 3 in.
A hand	= 4 in.
A span	= 9 in.
A cubit	= 18 in.
A military pace	= 30 in.
A link	= $\frac{1}{100}$ chain
A knot (nautical mile)	= 6086 ft.
A fathom	= 6 ft. (United States)
A fathom	= 6.08 ft. (British)
1 ell (English)	= 45 in.
1 ell (Dutch)	= 1.094 yd.
1 bolt	= 40 yd.
A chain	= 4 rods (66 ft.) = 20.11684 meters
A furlong	= $\frac{1}{8}$ mile
A league	= 3 knots
A cable length	= 120 fathoms (United States)
A cable length	= 608 ft. (British)

An International Geographical mile = $\frac{1}{15}°$ at equator = 24,350.3 ft.

A British nautical mile = 6,080.4 ft.

Linear Measure—French[1]

10 millimeters	= 1 centimeter
10 centimeters	= 1 decimeter
10 decimeters	= 1 meter
10 meters	= 1 dekameter
10 dekameters	= 1 hektometer
10 hektometers	= 1 kilometer
10 kilometers	= 1 myriameter.

A micron is $\frac{1}{1000}$ mm.; a millimicron = $\frac{1}{1000}$ micron; 1 angstrom unit = $\frac{1}{10}$ millimicron.

[1] The decimeter, dekameter, hektometer and myriameter are seldom used as compared with the other measures. When the metric system was devised the meter was supposed to be one ten-millionth part of the quadrant of the earth's surface. However owing to inaccuracies of measurement, this is only approximately true, and the meter must be defined, as the length of a standard bar of platinum kept in Paris, when measured at a temperature of zero degree centigrade.

Conversion Table, Linear Measure[1]

1 in. = 2.540005 cm.
1 ft. = 0.3048006 m.
1 yd. = 0.9144018 m.
1 mi. = 1.609347 km.
1 cm. = 0.3937000 in.
1 m. = 39.37000 in. = 3.28083 ft.
1 m. = 1.09361 yd. = 0.00062 mi.
1 km. = 0.62137 mi. = 3280.83 ft.

The old French measures and their equivalents are:

1 toise = 1.9490366 m.	1 pouce = 2.706995 cm.
1 pied = 0.3248394 m.	1 ligne = 0.225583 cm.

1 toise = 6 pieds = 72 pouces = 864 lignes

Square Measure—English

144 sq. in.	= 1 sq. ft.
9 sq. ft.	= 1 sq. yd.
30.25 sq. yd. 272.25 sq. ft.	= 1 sq. rod
160 sq. rd. 10 sq. ch. 4 roods 43,560 sq. ft.	= 1 acre
640 acres	= 1 sq. mi.
A square of flooring or roofing	= 100 sq. ft.
A section of land	= 1 mi. sq.
A township	= 36 sq. mi.
A board foot	= 1 ft. square × 1 in. thick

Square Measure—French

100 sq. mm.	= 1 sq. cm.
100 sq. cm.	= 1 sq. dm.
100 sq. dm.	= 1 sq. m. (centar)
100 sq. m.	= 1 sq. dekameter or ar
100 sq. dekameters	= 1 sq. hektometer (hektar)
100 sq. hektometers	= 1 sq. kilometer

[1] The foot is defined by United States law as being $^{3600}/_{3937}$ meters. Therefore in the United States 1 meter = 39.37 in. exactly. The British equivalent is, however, 1 m. = 39.370113 in. Apparently the British inch and the American inch were intended to be equivalent, but are not, though I have never heard of any notice being taken of this fact in commercial transactions. The value 1 meter = 39.37 in. has been used in all equivalents in this book.

Conversion Table, Square Measure

1 centar (1 sq. m.)	= 1550 sq. in.	= 10.764 sq. ft.
1 ar	= 119.6 sq. yd.	
1 hectar	= 2.47104 acres,	
1 acre	= 0.40469 hektar	

1 sq. cm.	= 1.5500 sq. in.
1 sq. meter	= 10.76387 sq. ft.
1 sq. km.	= 0.3861 sq. mi.
1 sq. in.	= 6.4516 sq. cm.
1 sq. ft.	= 0.092903 sq. m.
1 sq. mi.	= 2.589998 sq. km.

Cubic Measure—English[1]

1728 cu. in. = 1 cu. ft.
27 cu. ft. = 1 cu. yd.
128 cu. ft. = 1 cord
50 cu. ft. of square timber = 1 load
40 cu. ft. of unhewn timber = 1 load.
A board foot = 1 ft. square × 1 in. thick

Weight—English

Avoirdupois

16 drams (dr.)	= 1 ounce (oz.)
16 oz.	= 1 pound (lb.)
100 lb.	= 1 hundred-weight (cwt.)
20 cwt.	= 1 ton

Troy

24 grains	= 1 pennyweight (dwt.)
20 dwt.	= 1 oz. Tr.
12 oz. Tr.	= 1 lb. Tr.

The Avoirdupois
pound = 7000 grains = 14.5833 oz. Tr.
The Troy
pound = 5760 grains = 13.1657 oz. Avoir.
The Avoirdupois
ounce = 437.5 grains = 0.9115 oz. Tr.
1 ton = 29,166.66 oz. Tr.
1 ton = 0.89287 long ton
1 long ton = 1.12 short tons = 2240 lb.

(Troy weight is used in weighing gold, silver, platinum, etc. In weighing precious stones the metric carat = 200 mg., is now used.)

1 barrel of flour = 8 sacks = 196 lb.
1 barrel of pork = 200 lb.
1 barrel of cement = 4 sacks = 376 lb.

[1] For French cubic equivalents see under "Measures of Capacity." p. 143.

Weights—French

10 milligrams	=	1 centigram
10 decigrams	=	1 gram
10 dekagrams	=	1 hectogram
10 centigrams	=	1 decigram
10 grams	=	1 dekagram
10 hectograms	=	1 kilogram[1]
100 kilograms	=	1 metric quintal
1000 kilograms	=	1 metric ton (tonne) or millier

Conversion Table, Weight

1 oz. avoir.	=	28.34953 grams
1 lb. avoir.	=	453.59 grams
1 ton	=	907.18 kg.
1 gram	=	0.035274 oz. avoir. = 0.00220 lb.
1 kg.	=	35.27396 oz. avoir. = 2.2046223 lb.
1 metric ton	=	1.102311 tons = 0.9842 long tons
1 grain	=	64.799 mg.
1 dwt.	=	1.55517 g.
1 oz. Troy	=	31.1035 g.
1 lb. Troy	=	0.37324 kg.
1 gram	=	15.4324 gr. = 0.64301 dwt.
1 mg.	=	0.64301 dwt. = 0.03215 oz. Tr.
1 kg.	=	32.15074 oz. Tr. = 2.67923 lb. Tr.

The *libra* used in Spain, Portugal and Spanish America differs slightly from the U. S. pound, ranging from 1.012 in Portugal and Brazil to 1.016 Cuba and Porto Rico.

The Assay Ton.—A weight used by assayer such that 1 ton (2000 lb.) : 1 oz. Tr.:: 1 A.T.: 1 mg.; *i.e.*, if the assayer weighs out assay tons, each milligram of metal recovered represents 1 Troy oz.

Apothecaries Weight

20 grains	=	1 scruple (℈)
3 ℈	=	1 dram (ʒ)
8 ʒ	=	1 ounce (℥)
12 ℥	=	1 lb. Tr.

[1] When the metric system was devised, it was intended that 1 gram should equal the mass of 1 cubic centimeter of water at its greatest density (4°C.) This relation does not exactly hold, and it is necessary to define the gram as the one-thousandth part of a standard mass of platinum kept in Paris. At 4°C. the mass of 1 cc. of water differs so slightly from unity that for nearly all calculations no correction is necessary. A liter was intended to be equal to 1000 cc.. but was defined as the volume occupied by a kilogram of water at 4°C. and 760 mm. pressure. It is therefore equivalent to 1000.027 c.c. (de Lepinay, Benoit and Buisson.)

Apothecaries Measure

60 minims (m)	= 1 dram
8 drams	= 1 fluid ounce
16 fl. oz.	= 1 pt.

The apothecaries grain is equal to the Troy grain; the scruple to ⅚ of the pennyweight.

1 gr. = 64.799 mg. 1 ℈ = 1295.98 mg.
1 ℥ = 3887.94 mg. 1 fl. oz. = 29.5729 milliliters
1 milliliter (1c.c.) = 0.3381 fl. oz.

Measures of Capacity—English

Dry		Liquid	
2 pt.	= 1 qt.	4 gills	= 1 pt.
8 qt.	= 1 peck	2 pt.	= 1 qt.
4 pk.	= 1 bushel	4 qt.	= 1 gal.

31½ gal.	= 1 barrel (bbl.) U. S.
2 bbl.	= 1 hogshead (hhb.)
2 hhd.	= 1 pipe
42 gal.	= 1 bbl. (Standard Oil Co.), formerly a tierce
84 gal. (2 tierces)	= 1 puncheon

A liquid gallon (U.S.)	contains 231.0 cu. in.
An Imperial gallon	contains 277.408 cu. in.[1]
A bushel (U.S.)	contains 2150.42 cu. in.
An Imperial bushel	contains 2218.192 cu. in.[2]
A quarter	contains 8 Imperial bu.

NOTE.—It can be seen that the dry quart contains 67⅕ cu. in., while the liquid quart contains only 57¾ cu. in. There is therefore no royal road to reducing dry measures to wet equivalents, though the ratio is about 1: 1⅙ (1.16364).

1 Imperial gal.	= 1.20094 U. S. gal.
1 U. S. gal.	= 0.83268 Imp. gal.
1 Imp. bu.	= 1.03151 U. S. bu.
1 U. S. bu.	= 0.96945 Imp bu.
1 gal. (ale or beer)	= 1.2208 U. S. gal.

Grains per U.S. gal.	× 17.138	= parts per million
Grains per Imp. gal.	× 14.285	= parts per million
Parts per million	× 0.0583	= grains per U.S. gal.
Parts per million	× 0.700	= grains per Imp. gal.

[1] Sometimes given 277.274.
[2] Sometimes given 2219.28.

Measures of Capacity—French

1000 cu. mm.	= 1 c.c.
1000 c.c.	= 1 cu. dm. (liter)
1000 cu. dm.	= 1 cu. m.

In measuring wood, the cubic meter is called a ster.

10 milliliters	= 1 centiliter
10 centiliters	= 1 deciliter
10 deciliters	= 1 liter
10 liters	= 1 dekaliter
10 dekaliters	= 1 hectoliter
10 hectoliters	= 1 kiloliter

Conversion Tables, Cubic Measure

1 cu. in.	= 16.38720 c.c.
1 c.c.	= 0.06102338 cu. in. = 0.0000353 cu. ft.
1 cu. ft.	= 0.028317 cu. m.
1 cu. m.	= 35.31445 cu. ft. = 1.30794 cu. yd.
1 cu. yd.	= 0.764559 cu. m.

Liquid Equivalents

1 fl. oz.	= 29.5729 milliliters
1 milliliter	= 0.3381 fl. oz. = 0.061025 cu. in.
1 gill	= 1.1829 deciliters
1 deciliter	= 0.8454 gills
1 quart	= 0.94633 liters
1 liter	= 1.0567 quarts
1 U. S. gal.	= 3.78533 liters
1 dekaliter	= 2.6418 gal.

Dry Equivalents

1 pt.	= 0.550599 liters
1 deciliter	= 0.18162 pt.
1 qt.	= 1.10120 liters
1 liter	= 0.90810 quarts
1 pk.	= 0.08810 hectoliter
1 hectoliter	= 2.8378 bu.
1 bu. (U. S.)	= 0.35238 hectoliter
1 kiloliter	= 1.3079 cu. yd.

Circular and Angular Measure

60 sec. (″)	= 1 minute (′)
60 min. (′)	= 1 degree (°)
360 deg. (°)	= 1 circumference

In the higher mathematics another unit is used:

2π radians = 1 circumference

$\therefore$ 1 radian = 57.2957795° = 57° 17′ 44.806″

Time

60 sec. = 1 min.; 60 min. = 1 hr.; 24 hr. = 1 day

365.242218 solar days = 1 year

29 days 12 hr. 44 min. = 1 lunar month

A seconds pendulum = 39.138 in. = 0.9958 meters in the latitude of New York at sea level.

The period of a pendulum is $\pi\sqrt{\frac{l}{g}}$, where l is length, and g the acceleration due to gravity.

Miscellaneous

20 units	= 1 score	24 sheets	= 1 quire
12 units	= 1 dozen	20 quires	= 1 ream
12 dozen	= 1 gross	2 reams	= 1 bundle
12 gross	= 1 great gross	5 bundles	= 1 bale

1 atmosphere = 14.7 lb. per sq. in. = 29.922 in. of mercury = 33.9 ft. of water

Weight, Force or Pressure, Combined with Areas

1 atmosphere = 760 mm. of mercury = 29.9212 in. of mercury
= 10.3329 m. of water = 33.9006 ft. of water
= 1.03329 kg. per sq. cm. = 14.6969 lb. per sq. in.

1 barie = 1 dyne per sq. cm. = 0.00208870 lb. per sq. ft.

1 foot-pound = 13.8255 kg. cm. = 3.306×10^{-4} cal.

1 kg. per sq. m. = 14.2234 lb. per sq. in.

1 lb. carbon oxidized to CO_2 = 14,544 heat units.

EQUIVALENT VALUES OF ELECTRICAL AND MECHANICAL UNITS.

(H. Ward Leonard in "The Electrical Engineer," February 25, 1895. Revised November, 1907.)

From "Manuel for Engineers", Copyrighted by Charles E. Ferris, B. S.

Unit	Equivalent value in other Units.
1 Watt.	1. joule per second. .00134 H.-P. 3,412 heat-units per hour. .7373 ft.-lb. per second. .0035 lb. water evap. per hour from and at 212° F. 44.24 ft.-lbs. per minute. 1 lb. pull at half a mile per hour. (approx.)
1 Watt per sq. in.	8.19 heat-units per sq. ft. per minute. 6371. ft.-lbs. per sq. ft. per minute. .193 H.-P. per sq. ft.
1 Heat unit	1.055 watt seconds. 778. ft.-lbs. 107.6 kilogram meters. .000293 K. W. hour. .000393 H. P. hour. .0000688 lb. carbon oxidized. .001036 lb. water evap. from and at 212° F.
1 Heat-Unit per sq. ft. per min.	.122 watts per sq. in. .0176 K. W. per sq. ft. .0236 H. P. per sq. ft.
1 Kilogram meter.	7.233 ft.-lbs. .00000365 H.-P. hour. .00000272 K. W. hour. .0093 heat-unit.
1 lb. carbon oxidized with perfect efficiency.	14.544 heat-units. 1.11 lbs. anthracite coal oxidized. 2.5 lbs. dry wood oxidized. 21. cu. ft illuminating gas. 4.26 K. W. hours. 5.71 H.-P. hours. 11,315,000 ft.-lbs. 15. lbs. of water evap. from and at 212° F.
1 lb. water evap. from and at 212° F.	.283 K. W. hours. .379 H.-P. hour. 965.7 heat-units. 103.900 kg. m. 1,019,000 joules. 751.300 ft.-lbs. .0664 lb. carbon oxidized.

EQUIVALENT VALUES OF ELECTRICAL AND MECHANICAL UNITS.

(H. Ward Leonard in "The Electrical Engineer," February 25. 1895. Revised November, 1907.)

From "Manuel for Engineers", Copyrighted by Charles E. Ferris, B. S.

Unit	Equivalent value in other Units.
1 K. W. Hour.	1,000. watt hours. 1.34 H. P. hours. 2,654,200 ft.-lbs. 3,600,000. joules. 3,412. heat-units. 367,000. kilogram meters. .235 lb. carbon oxidized with perfect efficiency. 3.53 lbs. water evap. from and at 212° F. 22.75 lbs. of water raised from 62° to 212° F.
1 H. P. Hour.	.746 K. W. Hours. 1,980,000. ft.-lbs. 2.545. heat-units. 273.740 kg. m. .175 lbs. carbon oxidized with perfect efficiency. 2.64 lbs. water evap. from and at 212° F. 17.0 lbs. water raised from 62° F. to 212° F.
1 Kilo-Watt.	1,000 watts. 1.34 horse-power. 2,654,200 ft.-lbs. per hour. 44,240. ft.-lbs. per minute. 737.3 ft.-lbs. per second. 3,412. heat-units per hour. 56.9 heat-units per minute. .948 heat-units per second. .2275 lbs. carbon oxidized per hour. 3.53 lbs. water evap. per hour from and at 212° F.
1 H. P.	746. watts. .746 K. W. 33000. ft.-lbs. per minute. 550. ft.-lbs. per second. 2,545. heat-units per hour. 42.4 heat-units per minute. 707 heat-units per second. .175 lbs. carbon oxidized per hour. 2.64 lbs. of water evap. per hour from and at 212° F.
1 Joule.	1 watt second. .000000278 K. W. hour. .102 kg. m. .0009477 heat-units. .7373 ft.-lb.
1 Ft.-lb.	.1356 joules. 1.3883 kg. m. .000000377 K. W. hours. .001285 heat-units. .0000005 H.-P. hour.

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